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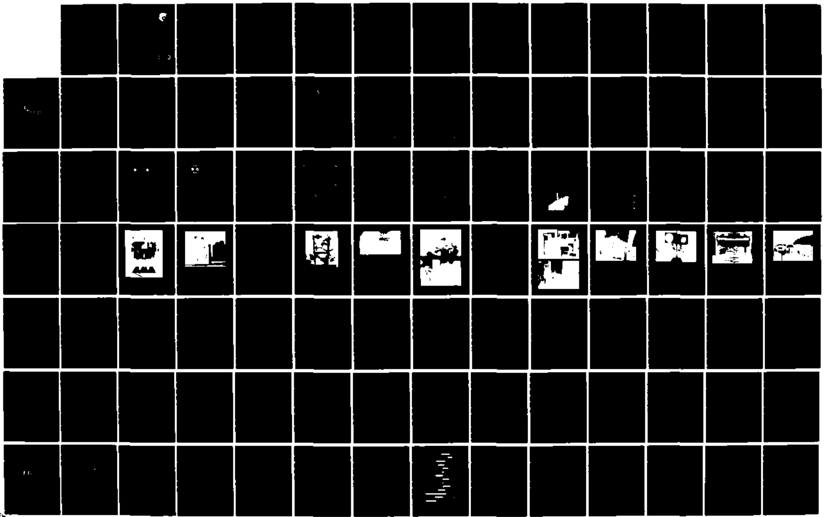

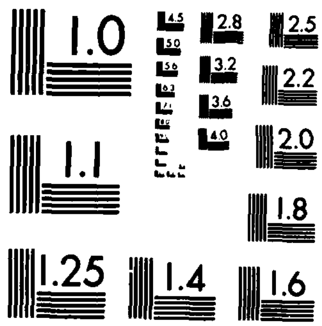
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AFWAL-TR-84-1162

AD-A151 113

FIBER OPTICS APPLICATION FOR MIL-STD-1760

Electronics Systems Technology
McDonnell Aircraft Company
P.O. Box 516
St. Louis, Missouri 63166

G.L. Weinstock
R. Poppitz

October 1984

Final Report for Period 15 May 1983 - 13 August 1984

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This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report documents the procedures and tests conducted to identify and validate one compatible set of fiber optic components which can fully meet MIL-STD-1760 performance and environmental requirements for airborne use. The methodology required for operational use, maintenance and integration of fiber optics into the MIL-STD-1760 connector and wire harness is also documented. Contents of the report include a component survey and selection, test plan documentation, test results, maintenance/repair procedures, specification development, etc.

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PREFACE

This report was prepared by the McDonnell Aircraft Company, a division of the McDonnell Douglas Corporation, St. Louis, Missouri, Electronic Systems Engineering Department under U.S. Air Force Contract No. F33615-83-C-1004. The program was administered by the Air Force Wright Aeronautical Laboratories (AFWAL), Wright Patterson AFB, Ohio. The Air Force Project Engineer directing the technical aspects of the study was Mr. John Slivinski, ASD/ENASA.

This report contains data to assist the U.S. Air Force in planning future applications of fiber optics data transfer in the armament buses of military aircraft by demonstrating that a fiber optics interconnect system compatible with the MIL-C-38999 connector size 16 contacts is qualified for aircraft use. Component, fabrication, installation, and maintenance/repair specifications are included in this report. This study was conducted during the months of May 1983 through August 1984.

Contributions to this report from Messrs. H. C. Freiberger, D. W. Shafferkoetter, R. S. Soloman, and D. E. Jaspering are gratefully acknowledged. The authors wish to acknowledge the technical assistance and guidance of Mr. E. A. Rosenkoetter. The principal investigator was G. L. Weinstock.

This report was submitted by the authors in December 1984.

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SECTION I

INTRODUCTION

1. GENERAL

Fiber optics offers attractive design options for information transfer systems with its advantages of wide bandwidth and electromagnetic noise immunity. The DoD has recognized these potential benefits by allocating positions in the MIL-STD-1760 Primary Interface Signal Set connector for two future fiber optics bus lines.

2. OBJECTIVE

For several years, users and several connector manufacturers have been interested in a set of fiber optics contacts interchangeable with size 16 electrical contacts for the MIL-C-38999 connector. Preliminary prototype testing had been sufficiently successful to define a program of full scale qualification for aircraft applications. The result was this contract sponsored by the U.S. Air Force ASD/ENASA with the objective to identify and qualify a set of fiber optics interconnect components which would meet MIL-STD-1760 performance and environmental tests requirements. The program has been successful. A MIL-STD-1760 fiber optics interconnect set has been identified and qualified. Specifications for the component parts and materials have been written. Procedures for fabrication, installation, Handling & use, maintenance/repair, and training have been developed. This fiber optics interconnect system is fully qualified and ready for aircraft use.

TABLE 7. FIBER OPTICS MIL-C-38999 TERMINATION DATA

Topic	Item				
Identification	Manufacturer Code	NN	DD	AA	SS
Configuration	Fiber Size Accepted	100/140 and Others	100/140	100/140 and Others	100/140 and Others
	Cavity Size	16	16	16	16
	Fiber Termination Method	Epoxy/Polish	Epoxy/Polish	Lens, Pigtail	Lens, Epoxy/Polish
	Interchangeability	Yes	Yes	Yes	Yes
	Strength Member Retention	Epoxy	—	Pigtail	Crimp
	Right Angle Strain Relief	—		—	—
	Auxiliary Alignment Parts	None	None	None	—
	Length Outside Insert	None	0.093	0 to 0.05	—
	Number of Parts	P-1(2), S-3(5)	P-1, S-2	P-1, S-1	P-4, S-4
	Weight, Mated Pair, Grams	0.95	1.55	—	—
Materials	Contact, Base	Stainless Steel	—	Brass	Stainless Steel Body
	Contact, Plating	None	—	Nickel	Nickel Ferrule
	Other	—	—	—	Sapphire Lens
Temperature Rating	Operating Range	−65°C to +125°C	—	−55°C to 150°C	−55°C to 125°C
	Storage Range	−65°C to +125°C	—	−55°C to 150°C	−55°C to 125°C
Optical Rating	Insertion Loss	1 dB Typical	1.2 dB	3 dB Maximum	2.5+0.5 dB
	Loss Variance	—	—	2 dB Mean + 1 dB	—
Vendor Test Data	Environmental	Thermal Shock	—	—	—
	Mechanical	Vibration/Durability	—	—	—
	Optical	<0.5 dB Changes	—	<3 dB	3 dB Max
Reliability	Durability	±0.2 dB/ 50 Matings	±0.2 dB/ 10 Matings	1,000 Matings	1,000+ Matings
	Fiber End Protection	Jewel Bearing	—	Lens	Lens
	Contamination Susceptibility	—	—	Low	Low
	Fungus Inert Materials	Yes	Yes	Yes	Yes
	Tensile Strength, lb	*25 min*	—	25*	33
Chemical	Solvent Resistence	Excellent	—	—	Excellent
	Flammability	Not Flammable	Not Flammable	MIL-STD-1344, 1012*	Low
Maintainability	Termination Time, Production	Typical	Typical	Pigtailed	5 min
	Termination Time, Field	Typical	Typical	Must Be Spliced	5 min
	Cleaning Ease	Simple	Simple	Simple	Simple
	Reusable Termination	No	No	No	Yes
Tooling	Special Tool(s) Required	Polish Die	Polish Die	None	Polish Die
	Cost of Special Tool(s)	—	—	—	$15
	Multiple or Single Source Tool(s)	—	—	—	Single
Experience	Prototype	Yes	Yes	Yes	Yes
	Production	Yes	No	No	No
	Flight	No	No	No	No
Availability	Cost/100 Pieces	$19.59/Mated Pair	—	$150/Mated Pair	—
	Delivery	Stock, 4 Weeks	—	4 Weeks	14 Weeks

*[illegible]

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TABLE 6. FIBER OPTICS CABLE REQUIREMENTS

Topic	Item	Requirements	X8	X3	X2	X6	X10	X5
Physical Size	Fiber, Core Diameter	100 microns	P	P	P	P	P	F
	Fiber, Cladding Diameter	140 microns	P	P	P	P	P	P
	Outer Jacket Diameter	0.065 - 0.109 in.	P	P	P	P	P	P
Environmental	Temperature, Max, Cont	71°C	P	P	P	P	P	—
	Temperature, 24 hr	– 57°C – + 95°C	P	P	P	P	P	—
Mechanical	Tensile Strength Terminated	25 lb	P	P	—	—	—	—
	Minimum Bend Radius, Fiber	0.125 in.	P	P	—	—	P	—
	Minimum Bend Radius, Cable	0.125 in.	P	P	—	—	—	—
	Abrasion Resistance	Good	P	P	—	—	—	—
	Indent Resistance	Good	P	P	—	—	—	—
	Handling Flexibility	Good	P	P	—	—	—	—
Chemical	Solvent Resistance	5M1945	P	P	P	P	—	—
	Flammability	Self-Extinging	P	P	—	—	—	—
Experience	Production Quantities	Required	P	P	—	—	—	—
	Flight	Preferred	P	—	—	—	—	—

F = Fail
P = Pass
— = Unknown

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The termination proposed by company "NN" uses a jewel bearing to provide fiber alignment. The jewel alignment system is factory installed to meet fiber diameter tolerances. Where maximum optical power throughput is desired, a jewel, to match the fiber within 5 microns, can be field installed. The ruby jewelis harder than the glass fiber. Polishing results in the fiber being slightly recessed, which provides inherent fiber end separation. The epoxy/polish termination method is simple, and the fiber end is accessible for cleaning. The company had performed tests to verify thermal shock, durability, and vibration capabilities using the 100/140 micron Figure 2 type cable being considered for this program. They consistently displayed optical losses of less than 2 dB. This agreed with tests performed on the terminations submitted with their proposal. Quantities of 2000 units have been produced.

(2) Unsuitable Candidates - Company "AA" proposed a termination based on a lens system. By expanding the beam of light with a lens, the signal is less susceptible to connector misalignment and to contamination. However, an important disadvantage is that it is available only as a factory termination. Company "AA" would supply both cable ends terminated to exact cable lengths or as pigtailed terminations requiring a splice to join to a cable. This severely restricts field operations and increases losses when splices are required. Additionally, simple flight qualified fiber optics splices are not readily available. Company "AA" specifies a maximum loss of 3 dB. Test data and sample parts were not available in time for the selection schedule. On the basis of data furnished and the possibility of additional splice interfaces, losses in this system appear to be excessive. Other limitations are a lack of production hardware, testing of the system, and high projected costs.

TABLE 5. (Continued) FIBER OPTICS CABLE DATA

Topic	Item	Data From Letter Response/Testing					
Identification	Manufacturer	X8	X3	X2	X6	X10	X5
Vendor Test Data	Environmental	Qualified	Qualified	—	—	—	—
	Mechanical	to	to	—	—	—	—
	Optical	5M1945	5M1945	—	—	—	—
Reliability	Tensile Strength						
	Fiber	—	—	—	—	11	—
	Cable	—	—	80	—	177	—
	Terminated	50	50	—	—	—	—
	Minimum Bend Radius, Fiber	0.125	0.125	—	—	0 125	—
	Radius, Cable	1.0	1.0	—	—	—	—
	Fungus Resistant Materials	Inert	Inert	Inert	—	—	—
	Abrasian Resistance	Good	Good	—	—	—	—
	Indent Resistance	Good	Good	—	—	—	—
	Handling Flexibility	Good	Good	—	—	—	—
Chemical	Solvent Resistance	5M1945	5M1945	5M1945	5M1945	—	—
	Flammability	IEEE-383-1974	MIL-W-22759/16	—	—	—	—
Maintainability	Strip Time (sec)	60	60	—	—	—	—
	Recladding Necessary	No	No	No	—	No	No
Tooling	Special Tool(s) Required	None	None	None	—	—	None
	No. of Special Tool(s)				—	—	
	Cost of Special Tool(s)				—	—	
	Durability of Tool(s)				—	—	
	Multiple Source				—	—	
Experience	Prototype	AV-8B, Bendix, IRAD	Sperry Univac, ITT-Can, Others	—	—	—	—
	Production	AV-8B	AV-8B	—	—	—	—
	Flight	AV-8B 4 A/C	None	—	—	—	—
Availability	Cost (per meter)	$2.12	$2.50	—	—	—	—
	Delivery (weeks)	6 - 8	Stock	6	—	—	—

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TABLE 5. FIBER OPTICS CABLE DATA

Topic	Item	Data From Letter Response/Testing					
Identification	Manufacturer	X8	X3	X2	X6	X10	X5
Configuration	Fiber Type	Glass	Glass	Glass	—	Glass	PCS
	Tube Construction	Semi-Loose	Tight	Tight	—	Tight	Loose
	Strength Member	Fiberglass	Fiberglass	Fiberglass	—	Kevlar	Kevlar
	Diameter, Core (microns)	100	100	100	100	100	120
	Diameter, Fiber (microns)	140	140	140	140	140	140
	Diameter, Buffer *(microns)*	500	500	900	—	500	250
	Diameter, Outer	0.105 ±	0.105 ±	0.105 ±	0.105 ±	0.080	—
	Jacket	0.003	0.003	0.003	0.003		
	Eccentricity	—	80%	—	—	—	—
	Ellipticity	—	—	—	—	—	—
	Weight 1,000 lb Max	6.8	6.8	6.8	6.8	3.0	—
Materials	Fiber	Glass/Glass	Glass/Glass	Glass/Glass	Glass/Glass	Glass/Glass	PCS
	Primary Jacket	Hytrel	Hytrel	Hytrel	Hytrel	Tefzel	Hytrel
	Cable Jacket	Tefzel	Tefzel	Tefzel	Tefzel	Hytrel	Tefzel
Temperature Rating	Operating Range	−55°C - 125°C	−55°C - 125°C	−55°C - 125°C	−55°C - 125°C	−55°C - 100°C	0°C - 55°C
	Storage Range	−55°C - 125°C	−55°C - 125°C	−55°C - 125°C	−55°C - 125°C	−55°C - 100°C	−55°C - 125°C
Optical Performance	Index Profile	Semi-Graded	Semi-Graded	Graded	—	Step	—
	Numerical Aperture	≥0.30	0.29	0.30	≥0.30	0.20	0.30
	Attenuation (dB/KM Max)	10	10	9.8	—	8.0	8.0
	Bandwidth (MHz-KM)	20 - 30	>100	—	—	—	—

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TABLE 4. VENDORS CONTACTED

Termination Companies	Cable Companies
AMP Incorporated	Amfox
Amphenol	Belden Corp
Augat Inc	Brand Rex Company
Bendix Corporation	Canstar Communications
Berg Connector Div - DuPont	Ensign Bickford Industries
Burndy Corporation	EOTec Corp
Deutsch Company	ITT Electro Optical Prod
G&H Technology Inc.	Mohawk Optical
GTE Sylvania	Phalo Optical Systems
Honeywell Electro-Optics	Pirelli Cable Corp
Holtek Optronics	Poly-Optical Products Inc
Hughes Aircraft Co.	Raychem Corp
ITT Cannon	Siecor Optical Cable
Matrix Science Corp	Times Wire and Cable
NEC Electronics USA Inc	Valtec Corp
OFTI	
Plessey Connectors Limited	
Raychem Corporation	
Socapex	
Switchcraft	
T&B Optoelectronics	
TRW Cinch Connectors	

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b. Contact Manufacturer Responses - Seven of the twenty-two termination companies contacted, responded. Four indicated they could meet the program schedule requirements outlined in the letter, and submitted proposals. Their response data is compiled in Table 7. Program requirements and vendor compliance are shown in Table 8. The connector termination companies are designated by double letters AA through ZZ.

(1) Suitable Candidates - The termination proposed by company "DD" employed the conventional epoxy/polish termination system for simplicity and ease of cleaning. Optical losses of less than 2 dB were consistently obtained. The termination extends up to 3/32 inch beyond the rear grommet. Normally, MIL-C-38999 contacts are fully terminated within the connector insert. This physical difference was of interest regarding any effect on flexing, strain relief, and axial tolerances. The company "DD" termination lacked production quantity experience, and testing beyond insertion losses.

TABLE 3. TERMINATION DATA NEEDS

Topic	Item
Specification	Manufacturer
	Part Number
Configuration	Fiber Size Accepted
	Cavity Size
	Fiber Termination Method
	Interchangeability
	Strength Member Retention
	Right Angle Strain Relief
	Auxiliary Alignment Parts
	Length Outside Insert
	Number of Parts
	Weight
Materials	Contact, Base
	Contact, Plating
	Other
Temperature Rating	Operating Range
	Storage Range
Optical Performance	Insertion Loss
	Loss Variance
Vendor Test Data	Environmental
	Mechanical
	Optical
Reliability	Durability
	Fiber End Protection
	Contamination Susceptability
	Fungus Inert Materials
	Tensile Strength
Chemical	Solvent Resistance
	Flammability
Maintainability	Termination Time, Production
	Termination Time, Field
	Cleaning Ease
	Reusable Termination
Tooling	Special Tool(s) Required
	Cost of Special Tool(s)
	Multiple or Single Source Tool(s)
Experience	Prototype
	Production
	Flight
Availability	Cost
	Delivery

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INFORMATION BELOW THIS LINE NOT PERTINENT TO ENGINEERING DESIGN

APPROVED CALLOUT	APPROVED VENDOR AND VENDOR'S DESIGNATION ▲	SUPERSED PARTS NOT APPROVED FOR PROCUREMENT FOR DISPOSITION DIRECTIONS SEE (6M148)
5M1945-001		NONE

PROCUREMENT REQUIREMENTS: 5M1945 (REV B)

RECEIVING INSPECTION REQUIREMENTS: 5M1945 (REV B)

▲ APPROVED VENDOR'S NAME AND FSCM NO.:

FSCM NO. 76301 . APPROVAL DATE: MAY 1980 REVISION:

5M1945
SHEET 3

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Figure 2. (Continued) Cable Fiber Optic, Procurement Specification

NOTES:
1. GENERAL: THE SPECIFICATION DESCRIBES THE REQUIREMENTS FOR A FIBER OPTIC CABLE MANUFACTURED IN ACCORDANCE WITH THE BASIC FIBER OPTIC SPECIFICATION, DOD-C-85045.
   1.1 PROCUREMENT SPECIFICATION: DOD-C-85045 EXCEPT AS SPECIFIED HEREIN.
   1.2 THIS STANDARD IS THE CONTROLLING DOCUMENT AND TAKES PRECEDENCE OVER OTHER DOCUMENTS REFERENCED HEREIN.
   1.3 REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATION FOR BID OR AS AUTHORIZED BY THE MCAIR STANDARDS ENGINEERING DEPARTMENT.
   1.4 VENDORS LISTED HEREIN ARE THE ONLY APPROVED SOURCE. ONLY VENDORS THAT ARE QUALIFIED TO SUPPLY CABLE TO DOD-C-85045 MAY BE CONSIDERED AS A SOURCE OF SUPPLY FOR 5M1945 CABLE AND SHOULD APPLY FOR APPROVAL VIA MCAIR STANDARDS ENGINEERING DEPARTMENT.
2. REQUIREMENTS: FINISHED CABLE SHALL MEET ALL THE REQUIREMENTS OF 5M1945 AND DOD-C-85045. WHERE THERE IS CONFLICT BETWEEN THE TWO DOCUMENTS, 5M1945 SHALL TAKE PRECEDENCE.
   2.1 OPTICAL
      2.1.1 OPTICAL PROPERTIES SHALL BE AS SPECIFIED IN TABLE II WHEN MEASURED AS REQUIRED IN DOD-C-85045.
   2.2 MECHANICAL
      2.2.1 MECHANICAL PROPERTIES SHALL BE AS SPECIFIED IN TABLE II WHEN MEASURED AS REQUIRED IN DOD-C-85045
   2.3 ENVIRONMENTAL
      2.3.1 THERMAL - THE CONTINUOUS TEMPERATURE RANGE IS 125°C TO -55°C.
   2.4 MARKING - ALL INTERIOR PACKAGES SHALL BE MARKED PER MIL-STD-129. EACH REEL OF CABLE SHALL BE IDENTIFIED WITH THE FOLLOWING INFORMATION LEGIBLY AND DURABLY PRINTED ON THE REEL.

MCDONNELL'S STANDARD PART NO.	PURCHASE ORDER NO
VENDOR'S NAME	EACH CABLE LENGTH AND TOTAL FOOTAGE
VENDOR'S PART NO.	MCDONNELL CIRCLE NO
VENDOR'S LOT NO.	
MONTH AND YEAR OF MFGR.	

   2.5 QUALITY ASSURANCE
      2.5.1 ALL 5M1945 CABLE SHALL MEET THE PERFORMANCE REQUIREMENTS OF TABLE III. GROUP A AND B INSPECTION (EXCEPT JACKET STABILITY AND DURABILITY OF IDENTIFICATION MARKING) IN DOD-C-85045 SHALL BE PERFORMED ON ALL SHIPMENTS OF CABLE TO MCAIR OR MCAIR'S DESIGNEE.
      2.5.2 CERTIFICATION OF COMPLIANCE SHALL BE PROVIDED WITH EACH LOT.
      2.5.3 QUALIFICATION INSPECTION (TABLE II OF DOD-C-85045) SHALL BE PERFORMED BEFORE SHIPMENT OF THE FIRST LOT OF CABLE AND ANYTIME THEREAFTER WHEN MATERIAL OR DIMENSIONS OF THE CONSTRUCTION ARE CHANGED. COPIES OF QUALIFICATION INSPECTION TEST DATA SHALL BE FORWARDED TO MCAIR STANDARDS ENGINEERING DEPARTMENT.
      2.5.4 MCAIR RESERVES THE RIGHT TO PERFORM ALL INSPECTIONS AND/OR TESTS TO INSURE COMPLIANCE WITH MIL-C-85045 AND THIS SPECIFICATION AND ACCEPT OR REJECT LOTS IN ACCORDANCE WITH MCAIR'S QUALITY ASSURANCE PROGRAM.
   2.6 PREPARATION FOR DELIVERY
      2.6.1 THE CABLE SHALL BE SUPPLIED IN MINIMUM LENGTHS OF 500 FEET. REELS OR SPOOLS SHALL BE CONSTRUCTED IN ACCORDANCE WITH PARAGRAPH 5.1.1.1 OF DOD-C-85045. WHEN MORE THAN ONE LENGTH OF CABLE IS PACKAGED ON A REEL, THE ENDS OF EACH LENGTH SHALL BE BROUGHT OUT AND SECURED TOGETHER TO PERMIT CONTINUITY CHECKS ON EACH LENGTH.
      2.6.2 THE REQUIREMENTS OF LEVEL A OF MIL-C-12000 SHALL BE MET.

TABLE III
PERFORMANCE REQUIREMENTS

TEST PER DOD STD-1678	RADIATION SOURCE	CENTER WAVELENGTH	SPECTRAL BANDWIDTH	SPECIMEN LENGTH	NA OF LAUNCHED RADIATION CONE	TEMP	TIME AT TEMP	MANDREL DIAMETER	MASS	NUMBER OF CYCLES	INCREMENT STATIC FORCE	TIME AT EACH FORCE
ACCEPTANCE PATTERN (6040)	BROAD BAND TUNGSTEN LAMP	900nm	20nm	3,280ft	[illegible]							
POWER TRANSMISSION AT ELEV. TEMP. (4010)				33ft			4 hr.					
POWER TRANSMISSION AFTER HUMIDITY (4020)				33ft								
POWER TRANSMISSION AFTER TEMP. CYCLE (4030)				33ft								
CYCLIC FLEXING (2010)				3.3ft				[illegible] in.	[illegible]	[illegible]		
IMPACT TEST (2030)				3.3ft					[illegible] lb	[illegible]		
TENSILE LOADING (3010)				3.3ft							[illegible] PSI	5 min.
COLD BEND (2020)				3.3ft		[illegible]°C	[illegible] hr	[illegible] in	[illegible] lb			

ELONGATION AND TENSILE STRENGTH FED-STD-228 METH. -3021	BONDING MATL AND FERRULE	L_1	L_2	RATE OF SPEED OF PWR GRIP	SPECIMEN NO	TEST FLUID	TEST TEMPERATURE	IMMERSION PERIOD
	AMPHENOL 906 EPOTECH	Shipping Length	1.64 ft		1	MIL-L-23699, lubricating oil synthetic base	48-50°C (118-122°F)	20 hrs
ATTENTUATION (6020)		Shipping Length	6.6 ft		2	MIL-H-5606, hydraulic fluid, petroleum base	48-50°C	20 hrs
					3	TT-I-735, isopropyl alcohol	20-25°C (68-77°F)	168 hrs
JACKET TENSILE STRENGTH AND % ELONGATION (FED STD 228, METH 3021/3031)					4	MIL-T-5624, Grade JP-4, turbine fuel, aviation	20-25°C	168 hrs
					5-6	MIL-A-8243, glycol and anti-icing fluid-undiluted and 60/40 anti-icing fluid/water dilution	48-50°C	20 hrs
					7	MIL-C-43616, cleaning compound aircraft surface-undiluted	48-50°C	20 hrs
CABLE TWIST (2050)	AMPHENOL 906 EPOTECH		6.6 ft		8	TT-M-268, methyl ethyl ketone	20-25C	168 hrs
					9	MIL-H-83306, hydraulic fluid, phosphate ester base	48-50C	20 hrs
FLUID IMMERSION (8030)					10	MIL-L-7808, lubrication oil, synthetic base	118-121°C (244-250°F)	5 mnts
					11-12	MIL-C-25769, cleaning compound, aircraft surface-undiluted and diluted with [illegible] parts water.	63-68°C (145-154°F)	20 hrs
					13-16	TT-S-735, Types I, II, III, VII, hydrocarbon test fluids	20-25°C	168 hrs
					17	Dielectric coolant fluid, synthetic, silicate ester base	20-25°C	168 hrs
					18	Solvent (b) of Method 215, MIL-STD-202	20-25°C	168 hrs
					19	Solvent (c) of Method 215, MIL-STD-202	20-25°C	168 hrs

1/ "Coolanol 25" (Monsanto) or equivalent

2/ 1, 1, 1-trichloroethane

3/ "Freon TMC" (Dupont) or equivalent (Azeotrope of dichloromethane and -1, 2, 2-trifluoroethane)

5M1945
SHEET 2

FORM NO. [illegible] • APPROVAL DATE: MAY 1980

REVISIONS

GP43-0686-5

Figure 2. (Continued) Cable Fiber Optic, Procurement Specification

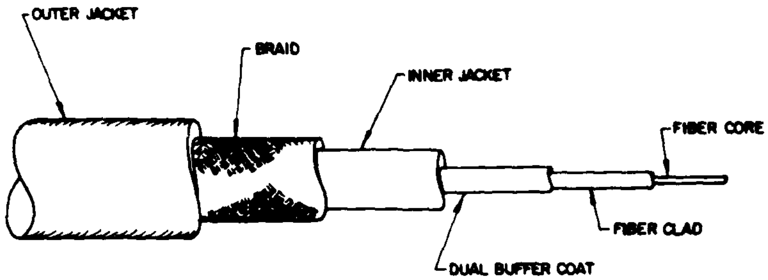

FIGURE B-1 -5M1945-001 OPTICAL FIBER

APPROVED CALLOUT
5M1945-001

TABLE I
CONSTRUCTION DETAILS

APPROVED CALLOUT	5M1945-001
OPTICAL FIBER	SEMI-GRADED, SINGLE FIBER CORE DIA. - .0039 + .00004 INCHES CLAD MATERIAL - SILICA GLASS CLAD DIA - .0055 + .0001 INCHES
BUFFER COAT	UV CURABLE, THERMOPLASTIC RESIN COAT DIA - .019 + 003 INCHES
INNER JACKET	HYTREL, TYPE 7246 INNER DIA - 025 INCHES MIN OUTER DIA. - 059 INCHES MAX
BRAID	TEFLON IMPREGNATED FIBERGLASS 150-1/2-2 ENDS 10 PICKS PER INCH
OUTER JACKET	TEFZEL 200 COLOR - VIOLET DIA. - 110 + 003 INCHES
CONCENTRICITY	80 MINIMUM FOR CORE, CLAD, INNER AND OUTER JACKET 70 MINIMUM FOR BUFFER COAT
TOTAL WEIGHT	6 8 LBS/1000 FEET
MINIMUM CABLE LENGTH	500 FT

TABLE II

	OPTICAL AND MECHANICAL PROPERTIES	
	APPROVED CALLOUT	5M1945-001
	MAX ATTEN @ 900 nm	1 5-3 0 db per 1000 ft
	NUMERICAL APERTURE	Steady State ≥ 30
B	CORE/CLADDING REFRACTIVE INDEX	1 48/1 4528
B	BANDWIDTH	100m Hz - 3300 ft
	FIBER TENSILE PROOF TEST	100,000 psi min
	BRAID BREAK FORCE	80 lbs
	JACKET TENSILE STRENGTH & ELONGATION	5,000 psi min , 200% min

DIMENSIONS IN INCHES: TOLERANCES UNLESS OTHERWISE SPECIFIED: .XX ± 0.03; .XXX ± 0.010; ANGLES ± ½°

FSCM NO. 76301	TITLE CABLE, FIBER OPTIC	CLASSIFICATION STANDARD PART DOCUMENT
PROCUREMENT SPECIFICATION DOD-C-85045		5M1945 SHEET 1 OF 3

APPROVAL DATE: MAY 1980 REVISION:

GP43-0586-4

Figure 2. Cable Fiber Optic, Procurement Specification

TABLE 2. CABLE DATA NEEDS

Topic	Item
Specification	Manufacturer
	Part Number
Configuration	Fiber Type
	Tube Construction
	Strength Member
	Diameter, Core
	Diameter, Fiber
	Diameter, Buffer
	Diameter, Outer Jacket
	Eccentricity
	Ellipticity
	Weight
Materials	Fiber
	Primary Jacket
	Cable Jacket
Temperature Rating	Operating Range
	Storage Range
Optical Performance	Index Profile
	Numerical Aperture
	Attenuation
	Bandwidth
Vendor Test Data	Environmental
	Mechanical
	Optical
Reliability	Tensile Strength
	Minimum Bend Radius, Fiber
	Minimum Bend Radius, Cable
	Fungus Resistant Materials
	Abrasion Resistance
	Indent Resistance
	Handling Flexibility
Chemical	Solvent Resistance
	Flammability
Maintainability	Stripping Time
	Recladding Necessary
Tooling	Special Tool(s) Required
	Number of Special Tool(s)
	Cost of Special Tool(s)
	Durability of Tool(s)
	Multiple or Single Source Tool(s)
Experience	Prototype
	Production
	Flight
Availability	Cost
	Delivery

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b. Cable Search - These requirements, a list of cable data needs (Table 2), and the cable specification being used in the production of the AV-8B aircraft (Figure 2) were submitted to 15 companies known to be involved in the manufacture of fiber optics cables, for their suggested candidates.

c. Termination Requirements - The requirements for the connector termination were determined to be:

- o size 16, MIL-C-38999, Series III
- o Terminate jacketed strength membered fiber optics cable such as MCAIR Standard Part Drawing ST5M1945 enclosed
- o Interchangeable with electrical contacts
- o Minimum 25-pound tensile strength from cable to connector
- o Easily cleaned and/or protected from contamination

d. Termination Search - These requirements, and a list of connector termination data needs (Table 3), were submitted to 22 companies known to be involved in the manufacture of fiber optics terminations, for their suggested candidates. A list of the cable manufacturers and the termination manufacturers is given in Table 4.

e. Delivery Requirement - In addition to the technical requirements, delivery of the selected components by 1 September 1983 was required.

4. COMPONENT SELECTION

a. Cable Manufacturer Responses - Seven of the 15 cable companies contacted responded. Four proposed cables that met the Figure 2 requirements, two proposed alternate cables, and one replied that it made fibers only. The responses are compiled in Table 5. The important characteristics of the cables are listed in Table 6, together with program requirements and the requirements met by each cable design. The names of the cable vendors are coded with a letter/number designator X1 through X15.

(1) Suitable Candidates - The company "X8" and company "X3" cables, built to Figure 2, met all of the Table 6 requirements. Therefore, these cables were chosen for this MIL-STD-1760 interconnect evaluation program.

(2) Unsuitable Candidates - Companies "X2" and "X6" proposed to provide cables to meet Figure 2 specifications, but had not produced them. Company "X10" submitted a cable design with a 100/140 micron glass/glass fiber. The outer jacket diameter of 0.080 inch was much smaller than the Figure 2 diameter of 0.105 inch, but was within the grommet sealing range of the size 16 insert cavity. Company "X10" also claims radiation hardness. However, the cable lacks complete test data, production, and flight experience. Company "X5" proposed a plastic clad silica (PCS) fiber with a hard cladding which did not require removal. The fiber was available in either a 140 or 230 micron cladding diameter. The larger diameter was attractive because it was less susceptible to connector misalignment and to contamination. Our prior testing of the 230 micron hard clad PCS fiber indicated good flexibility, but high and low temperature limitations inconsistent with MIL-E-5400 environmental requirements.

SECTION III

TASKS

1. GENERAL

The objective of this program was to fully environmentally and mechanically qualify a fiber optics interconnect system for MIL-STD-1760 based on a termination compatible with the Series III MIL-C-38999 connector. To meet this objective, the following program task plan was established.

a) Standards Review
b) Component Survey
c) Component Selection
d) Test Plan
e) Testing
f) Maintenance Practice Development
g) Specification Development

2. STANDARDS REVIEW

Applicable standards documents were reviewed to determine test procedures and test levels necessary to qualify a fiber optics harness for MIL-STD-1760 aircraft applications. These included the latest versions of MIL-STD-1760, DoD-STD-1678, MIL-STD-202, MIL-E-5400, MIL-STD-810, MIL-STD-781, MIL-T-5422, MIL-C-38999, MIL-I-16923, MIL-STD-1344, MIL-T-21200, and EIA RS-455. The results of this study were incorporated into a test matrix and used to establish component requirements.

3. COMPONENT SURVEY

a. Cable Requirements - The standards review and our fiber optics development and production experience were used to define interconnect cable and termination requirements for this program. The requirements for the cable were:

- Rugged as electrical cables; resistant to damage by crushing, indentation, kinking, flexing
- Compatible with termination to MIL-C-38999 Series III connectors, size 16 cavities
- Meet MIL-E-5400 Class 2 environment
- Meet MIL-W-5088 and MIL-C-38999 applicable mechanical characteristics
- Resistant to solvents and other chemicals commonly used on aircraft
- Buffered fiber capable of wrapping around 1/8 inch mandrel without breaking
- Suitable for field termination
- Minimum 25-pound tensile strength terminated to MIL-C-38999 termination

TABLE 1. QUALIFICATION TESTS

1	Epoxy Hydrolytic Stability
2	Fiber Flex
3	Cable Indent/Flex
4	Cable Flex
5	Cable Handling
6	Termination Evaluation
7	Insertion Losses
8	Tensile, Individual
9	Tensile, Individual @ −55°C
10	Maintenance Aging
11	Durability
12	Temperature Life
13	Humidity
14	Salt Spray, Unmated
15	Vibration
16	Vibration, Gunfire
17	Mechanical Shock
18	Thermal Shock
19	Sand and Dust
20	Harness Flex @ Connector, −40°C
21	Harness Flex @ Connector, 55°C
22	Tensile, Integrated Harness

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4. TESTING

Two cable/connector systems (primary and back-up) were selected for testing. The tests were conducted serially. The test program was successfully completed on schedule. Optical losses were consistent and within practical limitations. The interconnect system qualified by this program had insertion losses of 1.8 ± 0.6 dB. System quality was neither cumulatively nor significantly degraded through the test program.

5. QUALIFICATION

One complete interconnect system was qualified for continuous operation. The cable was a semi-graded index, 100/140 micron glass on glass fiber, with a fiber glass strength member and a Tefzel outer jacket. This cable was terminated into an epoxy/polish, fiber-to-fiber contact termination. A second system was partially qualified with the same cable terminated into a contact supplied by a different manufacturer. Qualification of this second interconnect system is contingent upon a design change to correct a specific contact problem.

6. PROCEDURES

Procedures for implementing this interconnect system into a military aircraft have been written and are included as part of this report. They include component and material standards, process specifications for the fabrication, installation, maintenance/repair, and training of personnel for these operations.

SECTION II

EXECUTIVE SUMMARY

1. BACKGROUND

The MIL-STD-1760 Aircraft/Store Interconnection System Standard has allocated two circuit positions in the MIL-C-38999 Series III Stores Management connector for fiber optics use. The fiber optics interconnect is desirable because it can accommodate high data rates, is immune to EMI, RFI, and lightning, and is light weight and small in size compared to coaxial cable. The objective of this program was to develop and qualify a fiber optics interconnect system for MIL-STD-1760. This objective was accomplished in accordance with the schedule shown in Figure 1.

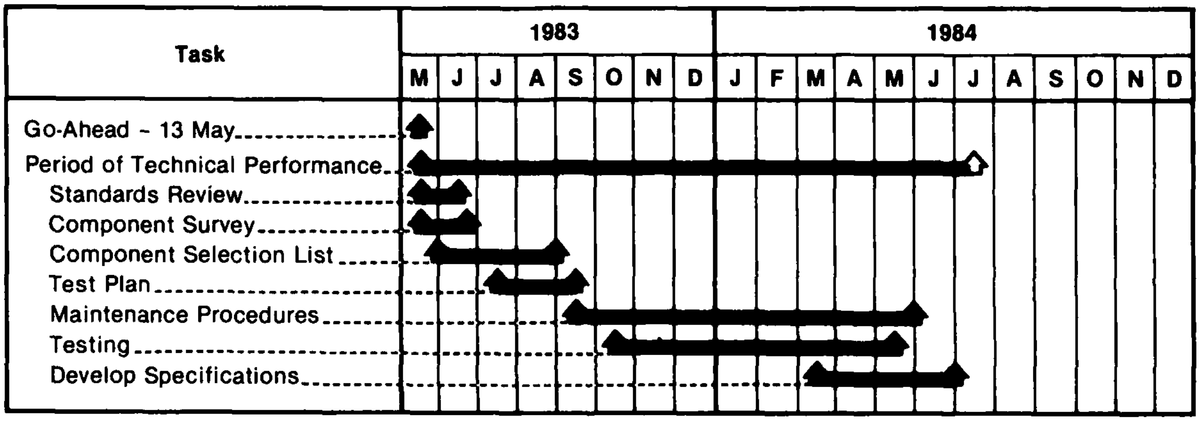

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Figure 1. Schedule
Fiber Optics Applications for MIL-STD-1760

2. REQUIREMENTS

Hardware and test requirements were established through a review of applicable standards documents. Manufacturers and suppliers of fiber optics cables and connectors were solicited for candidate components. From the replies submitted, primary and back-up cable and termination systems were selected.

3. TEST PLAN

A test plan was developed to evaluate both the individual components and specimen configurations based on MIL-STD-1760 applications. Synergistic testing to simulate field conditions included continuous measurement of optical power throughput. MIL-C-38999 and MIL-E-5400 test requirements were utilized as a basis for the test program. Additional MCAIR-developed tests were added to simulate actual installation handling and field usage and to supplement the military specifications. A list of the qualification tests is shown in Table 1.

TABLE 8. FIBER OPTICS TERMINATION REQUIREMENTS

Topic	Item	Requirement	NN	DD	AA	SS
Physical Size	MIL-C-38999, Series III	16	P	P	P	P
Optical	Insertion Losses	Max, 2 dB	P	P	—	—
Environmental	Operating Temperature Range	– 65°C to 125°C	P	—	P	P
Mechanical	Mating Durability	500	100	10	—	1,000
	Vibration	MIL-E-5400	16 hr/ MIL-C-38999	—	—	—
	Simple Termination	Minimum Parts	P	P	Pigtail	P
Experience	Production Quantities	Preferred	P	—	—	—
	Flight	Preferred	—	—	—	—

P = Pass
— = Unknown

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Company "GG" had an active development program for these termination components, but it offered no availability forecast.

Company "HH" furnished a prototype contact, which would meet the 125°C temperature requirements, in a size 12 which could be terminated quickly using a cleave/clamp method, but it could not guarantee a size 16 version within the program schedule.

Company "SS" also proposed a termination with a lens system utilizing the expanded beam principle, but this method permitted normal field termination. The fiber is epoxy/polish terminated into a ferrule which, in turn, is inserted into the lens assembly. The disadvantage of this system is the higher losses (up to 3 dB) associated with three interfaces (epoxy, lens, epoxy) compared to the single interface of the epoxy/polish method. Test data and a sample set of terminations were not available in time for the selection schedule. Previous tests on a size 12 version showed reasonable losses, but true insertion loss measurements were not possible with the company "SS" pigtail terminations. Limitations of this system are a lack of production hardware and system testing.

The company "YY" development was also based upon a size 12 termination. Its lens design in a size 16 was not expected to be available until early 1984.

(3) Primary Selection - The company "NN" epoxy/polish system was the first choice of terminations for the test program because of its consistently low losses, and the extent of successful vendor testing. Also, it is the only termination which has been produced in quantity. The company "NN" termination was selected as the primary termination system.

(4) Alternate Selection - The company "DD" termination was chosen as the alternate termination system because of its consistently low optical losses. A summary of the strengths and weaknesses of the termination systems submitted is presented in Table 9.

TABLE 9. STRENGTHS/WEAKNESSES, TERMINATION SYSTEMS SUBMITTED

Manufacturer Code	NN	DD	AA	SS
Strengths	1. Consistent Low Losses 2. Good Vendor Testing 3. Production Parts Available 4. Low Cost 5. Jewel Termination. Factory Installed or a Select Fit Jewel.	1. Consistent Low Losses	1. Lens System Is Less Susceptible to Alignment Problems and to Contamination.	1. Lens System Is Less Susceptible to Alignment Problems and to Contamination.
Weaknesses	1. Termination Time of Epoxy/Polish System.	1. Termination Time of Epoxy/Polish System. 2. Only Prototype Parts Have Been Built. 3. Lack of Testing	1. Available Only as a Factory Terminated Pigtail (Field Use Requires Splicing, Adding Another Set of Losses). 2. High Losses 3. Lack of Testing 4. No Hardware Parts Submitted. 5. High Cost	1. High Losses 2. Lack of Testing 3. No Hardware Parts Submitted.

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c. Connectors - The preferred test connector configuration for MIL-STD-1760 was the MIL-C-38999 Series III connector with a 25-20 insert configuration. However, no connector manufacturers had tooled the lanyard version of this connector, and none could promise delivery before the end of 1983.

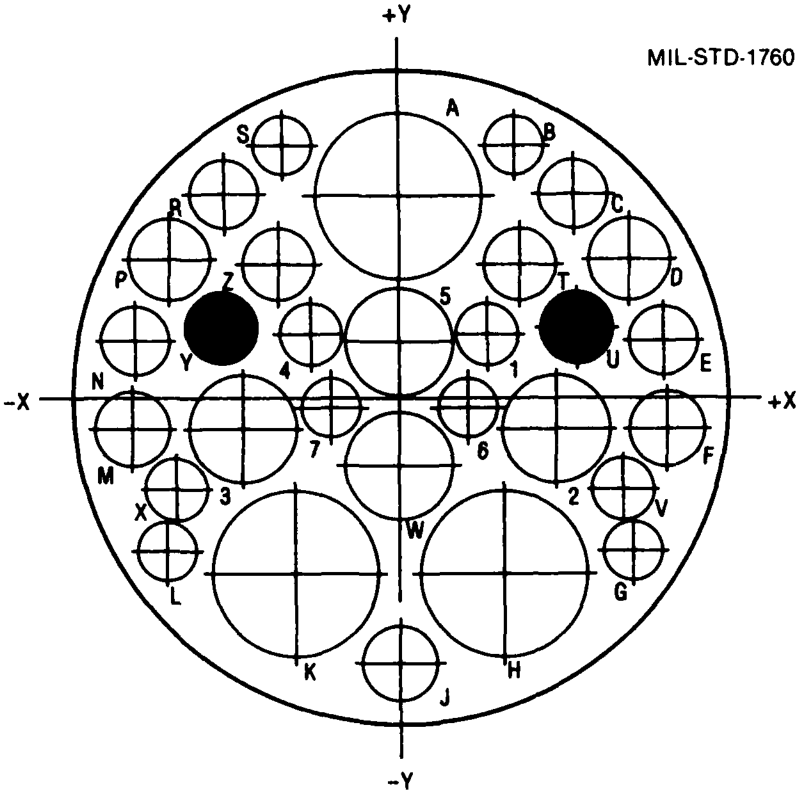
(1) Selected Configuration - To meet the program schedule, a 25-46 insert configuration was used for the test program. This configuration provides four size 16 cavities located similarly to the 25-20 size 16 cavities reserved for fiber optics. Figure 3 shows the insert configurations.

(2) Substitute Components - Since the specific MIL-C-38999 parts were not available, proprietary versions were used as follows:

Receptacle, Wall Mount, Bendix #TVPOORW-25-46P
Plug, Straight, Bendix #TVO6RW-25-46S
Plug, Lanyard Release, Bendix #88-556573-GS

Insert Arrangement, Electrical Connector
Shell Size 25

MIL-STD-1760 (Not Tooled)



in.	mm	in.	mm
0.018	0.46	0.275	6.99
0.060	1.52	0.312	7.92
0.061	1.55	0.317	8.05
0.099	2.51	0.352	8.94
0.111	2.82	0.353	8.97
0.115	2.92	0.357	9.07
0.131	3.33	0.407	10.34
0.136	3.45	0.411	10.44
0.141	3.58	0.450	11.43
0.183	4.65	0.466	11.84
0.195	4.95	0.467	11.86
0.208	5.28	0.511	12.98
0.234	5.95	0.530	13.46
0.243	6.17	0.537	13.64
0.270	6.86	0.541	13.74

Contact Location	x	y
A	0.000	+ 0.407
B	+ 0.234	+ 0.511
C	+ 0.352	+ 0.411
D	+ 0.466	+ 0.275
E	+ 0.530	+ 0.111
F	+ 0.537	− 0.060
G	+ 0.467	− 0.312
H	+ 0.208	− 0.353
J	0.000	− 0.541
K	− 0.208	− 0.353
L	− 0.467	− 0.312
M	− 0.537	− 0.060
N	− 0.530	+ 0.111
P	− 0.466	+ 0.275
R	− 0.352	+ 0.411
S	− 0.234	+ 0.511
T	+ 0.243	+ 0.270
U	+ 0.357	+ 0.136
V	+ 0.450	− 0.183
W	0.000	− 0.131
X	− 0.450	− 0.183
Y	− 0.357	+ 0.136
Z	− 0.234	+ 0.270
1	+ 0.195	+ 0.115
2	+ 0.317	− 0.061
3	− 0.317	− 0.061
4	− 0.195	+ 0.115
5	0.000	+ 0.099
6	+ 0.141	− 0.018
7	− 0.141	− 0.018

Shell Size	Arrangement Number	Number of Contacts	Size Contacts	Service Rating	Contact Location
		3	8	Triaxial	A, H, K
		4	12	Coaxial	W, 2, 3, 5
25	− 20	13	16	Inst	C, D, E, F, J, M, N, P, R, T, U, Y, Z
		10	20		B, G, L, S, V, X, 1, 4, 6, 7

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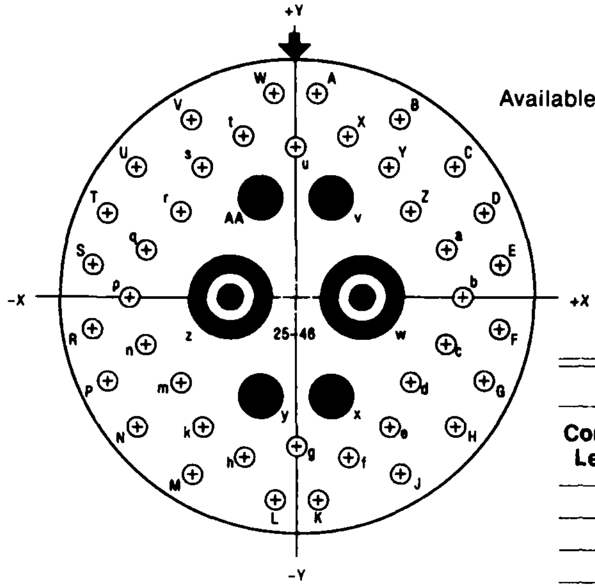
Figure 3. Insert Configurations



Available

in.	mm	in.	mm	in.	mm
0.065	1.65	0.245	6.22	0.420	10.67
0.079	2.01	0.265	6.73	0.424	10.77
0.097	2.46	0.275	6.99	0.426	10.82
0.125	3.18	0.297	7.54	0.466	11.84
0.136	3.45	0.337	8.56	0.493	12.52
0.180	4.57	0.390	9.91	0.531	13.49
0.217	5.51	0.395	10.03	0.533	13.54

Contact Location

Contact Letter	Location		Contact Letter	Location	
	x Axis	y Axis		x Axis	y Axis
A	+0.065	+0.533	a	+0.390	+0.125
B	+0.275	+0.466	b	+0.426	0.000
C	+0.420	+0.337	c	+0.390	+0.125
D	+0.493	+0.217	d	+0.297	−0.217
E	+0.531	+0.079	e	+0.245	−0.337
F	+0.531	−0.079	f	+0.136	−0.424
G	+0.493	−0.217	g	0.000	−0.395
H	+0.420	−0.337	h	−0.136	−0.424
J	+0.275	−0.466	k	−0.245	−0.337
K	+0.065	−0.533	m	−0.297	−0.217
L	−0.065	−0.533	n	−0.390	−0.125
M	−0.275	−0.466	p	−0.426	0.000
N	−0.420	−0.337	q	−0.390	+0.125
P	−0.493	−0.217	r	−0.297	+0.217
R	−0.531	−0.079	s	−0.245	+0.337
S	−0.531	+0.079	t	−0.136	+0.424
T	−0.493	+0.217	u	0.000	+0.395
U	−0.420	+0.337	v	+0.097	+0.265
V	−0.275	+0.466	w	+0.180	0.000
W	−0.065	+0.533	x	+0.097	−0.265
X	+0.136	+0.424	y	−0.097	−0.265
Y	+0.245	+0.337	z	−0.180	0.000
Z	+0.297	+0.217	AA	−0.097	+0.265

Shell Size	Arrangement Number	Number of Contacts	Size Contacts	Service Rating	Contact Location	Supersedes Document
25	−46	2	No. 8 Coaxial	Coaxial	z, w	MS20057-46
		4	16	I	AA, v x, y	
		40	20		All Others	

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Figure 3. (Continued). Insert Configurations

d. Auxiliary Components - The following is a list of the auxiliary connector hardware utilized to fabricate the #25 shell size test specimens. Connector cavities not filled with fiber optics circuits were filled with appropriate electrical circuitry. Harness construction was typical of MIL-STD-1760 applications.

#8 Coaxial Contact, Male, Bendix #21-33102
#8 Coaxial Contact, Female, Bendix #21-33101
#20 Contact, Electrical, Pin, M39029/58-363
#20 Contact, Electrical, Socket, M39029/56-351
Strain Relief, Straight, Bendix #10-552681-259
Strain Relief, Right Angle, Bendix #10-552682-259
Backshell, EMI, 90°, Glenair G7056-25-NF
Backshell Extender, Electrical, Glenair #320HS002NF25-3
Insertion/Extraction Tool, MS27534-16
Coaxial Cable, RG195 A/U
Wire, Hookup, #20, M81381/7-20-2
Braid, Textile, Nomex
Braid, Metal, Tin Plated Copper
Polishing Fixture, Per Manufacturer's Recommendations

5. TEST PLAN

a. Test Objective - The test objective was to flight qualify a fiber optics interconnect harness utilizing MIL-C-38999 Series III connectors. Included are the following requirements:

- Size and performance per MIL-STD-1760 and MIL-C-38999
- Environmental operation per MIL-E-5400 and MIL-C-38999
- Fiber optics terminations interchangeable with size 16 electrical contacts
- Minimum 25-pound tensile break strength between cable and termination
- A field serviceable and replaceable termination

b. Test Strategy - The test strategy was built on the following key elements:

- Realistic specimen configuration
- Synergistic testing
- Static and dynamic measurements
- Individual component tests

(1) Realistic Specimen Configuration - The test specimens were configured as shown in Figure 4. They accurately represented MIL-STD-1760 configurations, incorporating two alignment schemes (companies "NN" and "DD" termination systems), a full complement of electrical and fiber optics cables, both lanyard and non-lanyard plug Series III connectors, straight and right angle strain reliefs, metal braiding, textile braid jackets, and open harness construction.

(a) Specimens A and B - One harness (specimen A) utilized the standard non-lanyard type MIL-C-38999 Series III connectors, while another (specimen B) included a lanyard release plug of the same Series III connector. As space limitations often dictate the use of right angle connectors, a right angle strain relief backshell was used on specimen B.

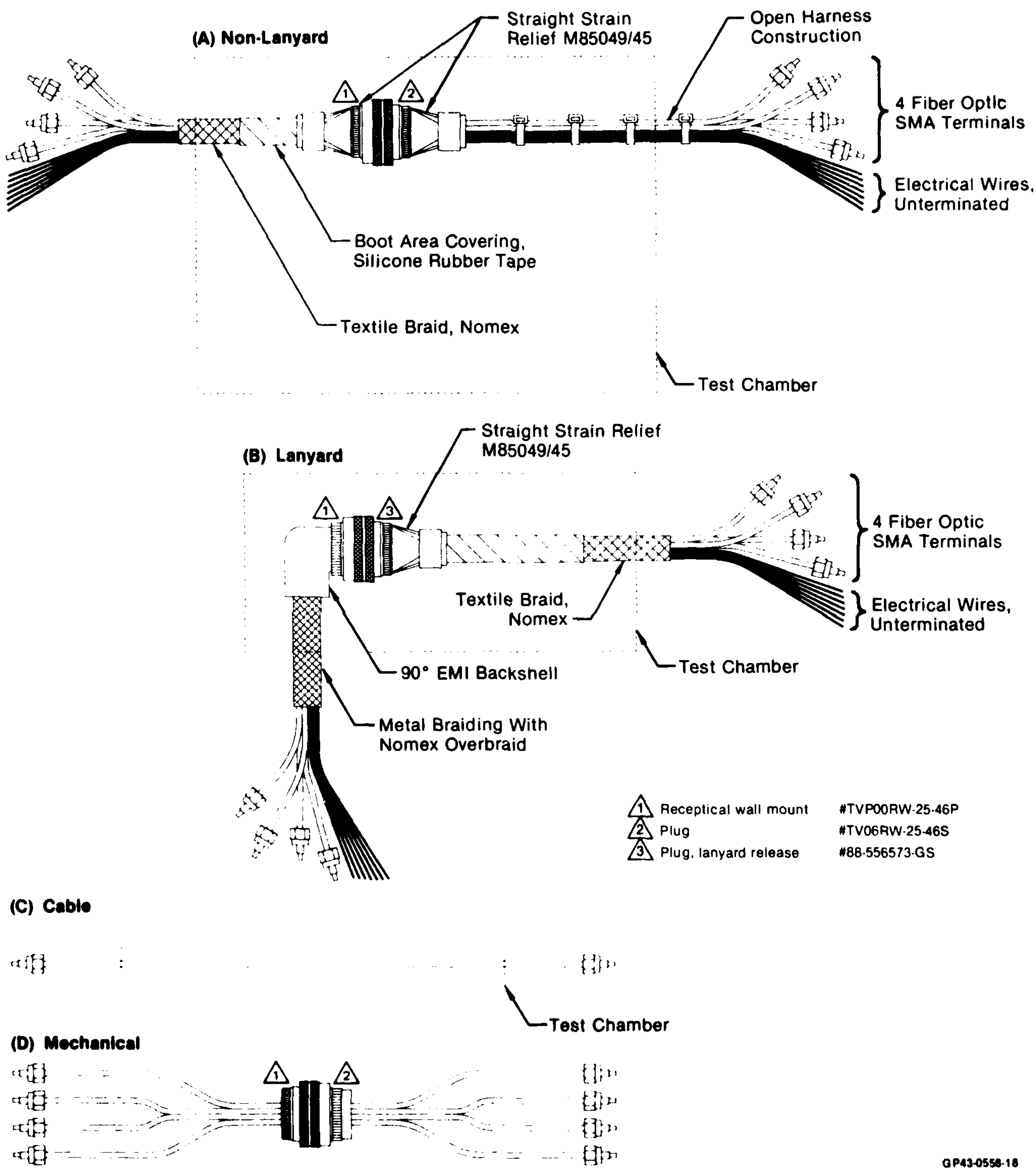

Figure 4. Specimen Configurations

(b) Specimen C - The control cable (specimen C) with terminations residing outside the testing environment was used as a reference. This permitted separation of the incremental losses incurred during the test environment into cable and connector components.

(c) Specimen D - A separate pair of Series III bayonet type connectors without strain relief (specimen D) was used in the termination evaluation to determine the basic cable/connector tensile capabilities.

(d) Harness Configuration - Both Aircraft Station Interface (ASI) and Mission Store Interface (MSI) harnesses are often protected with an overall metal braiding for EMI and/or abrasion protection. Therefore, one harness portion of the lanyard release specimen was fabricated with metal braiding and the associated EMI backshell hardware to simulate typical MIL-STD-1760 aircraft/store requirements. Harness segments were formed using both the conventional open harness construction and the high density compact (textile braiding) system. This provided a total of three typical harness types for evaluation.

(2) Synergistic Testing - Synergistic testing is a key element in the test plan to duplicate flight conditions in laboratory testing. The testing was accomplished in a number of ways. The test specimen configuration (Figure 4) included stresses caused by the right angle strain relief backshell, the braid, the straps, and other materials used to form the harness, and by the large mass of electrical circuitry which was a part of the hybrid harness. The test configurations (Figure 5) also simulated actual aircraft installations. The test harnesses were mounted on the vibration plate per MIL-W-5088 requirements, and the mandrel/weights configuration employed realistic tensile, compressive, and bend stresses. Finally, tensile and flex tests were made at temperature extremes. Tensile on the individual cables were performed at room temperature and at -55°C. Harness flexing was accomplished at -40°C and at 55°C, the temperature extremes specified by MIL-T-21200 for Class 2 flight line service operations.

(3) Static and Dynamic Measurements - The optical throughput was monitored in all testing. Initial and final static measurements were recorded for each test sequence. Wherever feasible, dynamic continuous measurements (every 15 seconds) were also obtained. In reporting the test results, the dynamic continuous measurements were used whenever available. The continuous measurements provide greater accuracy because the source, detector, and all necessary connecting cables were undisturbed throughout the test sequence. The change in throughput represents the effect of the test sequence. In the static initial/final measurements, the connections to the source and detector were disconnected after the initial measurement, and were reconnected for the final measurement. These connections were made with threaded SMA (single-channel coaxial type) connectors. The connectors were indexed, but repeated measurements using this method can vary up to 1 dB. Control cables, without terminations within the test environment, were used to separate the effects on the cable from those on the connector.

(a) Measurement Approach - The requirement for dynamic testing of connector performance demands special optical test equipment and instrumentation. Two approaches to the test system implementation are feasible. It can be based on synchronous measurement techniques, or it can be totally asynchronous using a constant-radiance source. The synchronous method requires a mechanical chopper, reference optical detector, and synchronous detection equipment such as a lock-in amplifier, in addition to the primary optical detector, for each main signal

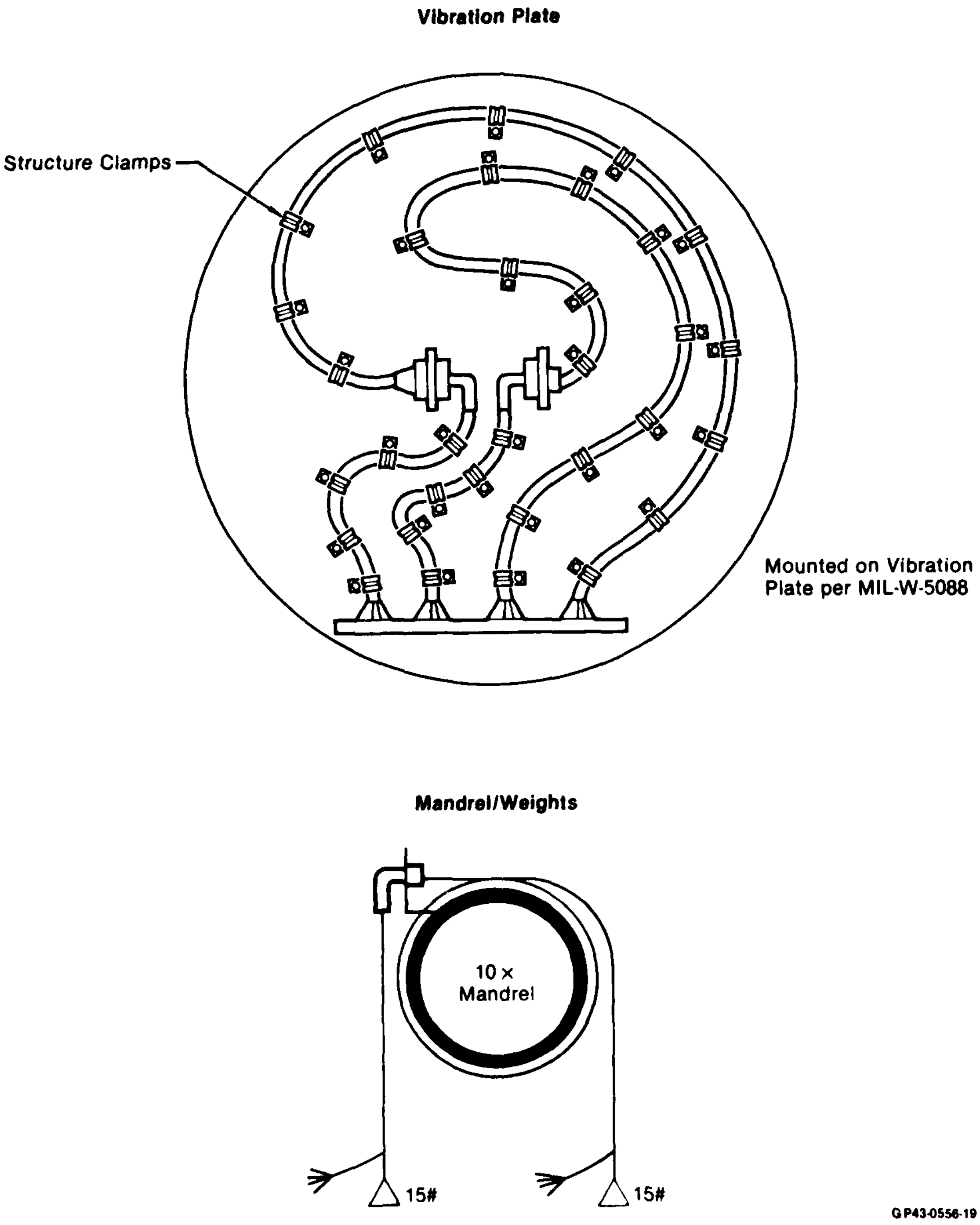

Figure 5. Test Configurations

channel. Thus, it is an expensive test set-up. The asynchronous method uses a source and detector or power meter for each channel. The detector output is compared to its output from a reference optical input if a ratiometric measurement is desired. The only critical requirement is that the optical source and detector be exceptionally stable for the duration of the test. Because of the economies of the asynchronous approach, and our experience and success in using it, this approach was selected.

(b) Optical Source - Since numerous tests were conducted over many hours, it was imperative that the optical source exhibit exceptional stability of output power with ambient variables, such as temperature. Without this stability, it is nearly impossible to distinguish between test equipment and test sample variability. This feature is also crucial in optical fiber loss measurement systems which rely on ratiometric techniques. The light source drift between reference and test measurements will affect the accuracy of the resulting decibel loss calculation. Although LED sources are less susceptible to short term output power fluctuations than are injection laser diodes, LEDs nevertheless have a finite lifetime and a non-zero temperature coefficient.

(1) Source Stabilization - Unlike many LED source stabilization circuits, which test source current for changes from a baseline, our approach was to sample the optical power output directly. If the sampling is done efficiently, that is, without using a significant portion of the source output, this approach proves to be superior in terms of long term stability for all parameters. MCAIR has developed a very effective sampling technique. The resulting controlled-LED source was used in this program. As shown in Figure 6, the circuit is a straightforward application of negative feedback techniques. A stable reference is set up and used for comparison. The light source is biased on, and a small portion of the output power (approximately -30dBm) is fed to a photodiode. The resulting photocurrent is amplified and compared with the stable reference. Any change in the output power is sensed and used to dynamically adjust the light source bias to provide a constant optical power output.

(2) Optical Output Power Tap - One unique feature of the stabilized light source is the method used to tap the output optical power. The light source used is a Honeywell SE3352 LED mounted in a flanged receptacle. A hole is drilled in the side of the receptacle to allow detection of a portion of the light emitted by the LED, but uncaptured by the output fiber. The light leaking out of that port, which is proportional to the actual power coupled into the output fiber, is sampled by a photodiode mounted in close proximity to the hole. The photodiode is positioned by set screws for optimum coupling.

(3) Stabilized Source Assembly - Figure 7 shows the machined housing assembly which holds the diodes and output optical fiber. Twelve of these controlled-LED source units were used to provide continuous, stable sources for up to twelve circuits.

(c) Optical Detector - Since many tests were monitored dynamically, it was necessary to employ a detector which had sufficient sensitivity and speed to respond to the fastest event anticipated. The optical sources used in the controlled-LED sources deliver enough power to the typical optical fiber that, even with the connector insertion loss added, there was adequate power incident on the detector to use relatively inexpensive silicon PIN photodiodes. Terminated in a low impedance, this detector was quite adequate to meet all program requirements.

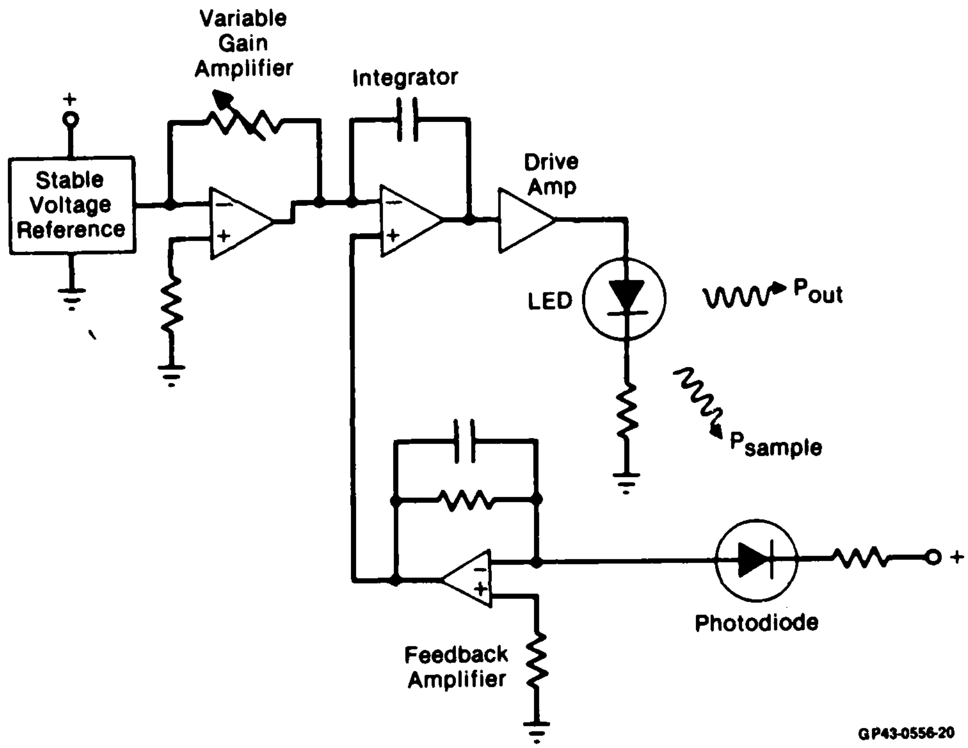

Figure 6. Stabilized Light Source Diagram

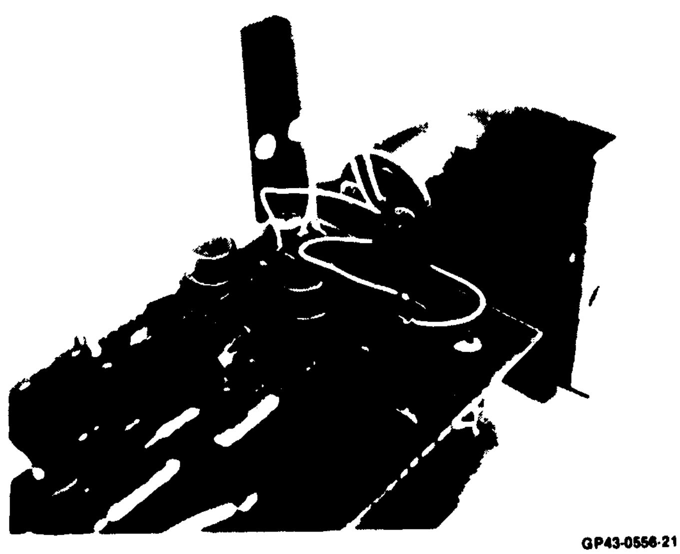

Figure 7. Stabilized Source Assembly

(d) Electronic Instrumentation - A block diagram of the instrumentation used on this program is shown in Figure 8. The output of the optical detector/preamplifier for each channel was connected to two recording systems. A Gould/Brush Model 200 eight-channel strip chart recorder was used to record relatively slow events; i.e., those which occur at low audio rates. The output was a real-time, paper chart recording of the throughput optical performance of each channel, as well as data pertinent to the stimulus. The other recording system began with a continuity detector consisting of a fast threshold detector and latch. It sensed a change in signal level, or momentary dropouts, that lasted 1 microsecond or longer. The John

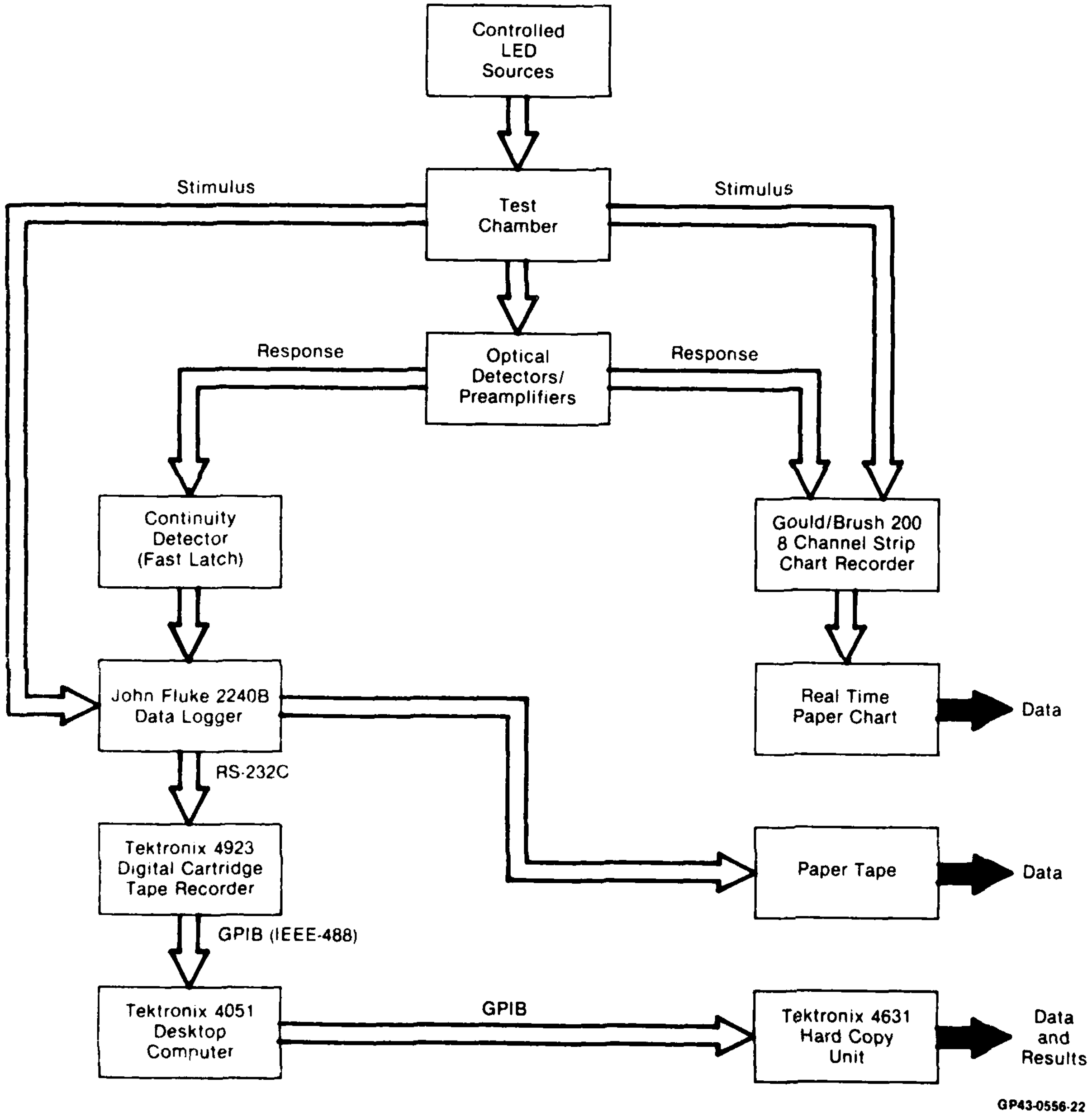

Figure 8. Instrumentation

Fluke Model 2240B Data Logger scanned all data channels and their stimuli to give an immediate print-out on paper tape of any anomalies. It also provided a digital output for the permanent recording of all data on a Tektronix 4923 Digital Cartridge Tape Recorder. The tape cartridge was then inserted into the Tektronix 4051 Desktop Computer system where the data was reduced, plotted, and printed on a Tektronix 4631 Hard Copy Unit.

(4) Individual Component Tests - The components of the fiber optics interconnect system were tested individually to ensure maximum confidence in subsequent testing of the components as an interconnect system. The first nine test sequences covered the qualification of the epoxy, the fiber and cable, and the termination.

c. Test Matrix - The test matrix is shown in Table 10. This matrix provides a summary of the tests performed, the sequence of testing, the method, the specimen configuration, the test configuration, and the type of throughput measurement.

d. Test Rationale and Procedures - The test procedures detailed reflect a broad spectrum of mechanical, optical, and environmental tests, including military and industry standards, and tests based on electrical interconnect qualification experience on fighter aircraft.

(1) Epoxy Hydrolytic Stability - Sequence 1

(a) Rationale - The epoxy used for contact termination must have chemical stability under the long term, combined extremes of high temperature and humidity.

(b) Procedure - The MIL-I-16923 test procedure was used. Cured specimens of the epoxy were measured for Shore D hardness and for electrical conductivity. One set of specimens was exposed to 120 days of 95% relative humidity at 160°F. The other set was used as a control, remaining at laboratory ambient. The measurements were repeated following the test exposure.

(2) Fiber Flex - Sequence 2

(a) Rationale - Installation of interconnect in an aircraft, particularly fighter aircraft, may subject the cables to non-cyclic flexing that may be more extreme than the minimum bend radius requirement for the installed interconnect.

(b) Procedure - DoD-STD-1678, Method 2010, Procedure I, Cyclic Flexing was modified to provide a single 360° wrap around an 0.125 inch mandrel. Three fibers, each 12 inches long, with buffer coating, were evaluated.

(3) Cable Indent/Flex - Sequence 3

(a) Rationale - Indent damage to cables may be incurred during installation, or during the service life of the aircraft. When the damage occurs near the connector, flexing of the cable during normal mating and unmating procedures may cause fiber breakage. The test conditions were selected to duplicate failures of bunch fiber cables, which had been experienced on the prototype YAV-8.

(b) Procedure - DoD-STD-1678, Method 2010, Procedure I was modified to change step 3. A 1.1 kg weight was dropped from a height of 1 inch onto the test cable positioned across the folded edge of a 2 1/4 x 1/8 inch piece of aluminum. The

TABLE 10. TEST MATRIX

Sequence	Name	Test: MIL-E-5400	Test: DOD-STD 1678	Test: MIL-C-38999	Test: EIA-FOTP	Test: MIL-J-16923	Method	Specimen Configuration: Non-Lanyard (A)	Specimen Configuration: Lanyard (B)	Specimen Configuration: Cable (C)	Specimen Configuration: Mechanical (D)	Test Configuration: Unmounted	Test Configuration: Vibration Plate	Test Configuration: Mandrel/ Weights	Throughput Measurement: Initial/ Final	Throughput Measurement: Continuous
1	Hydrolytic Stability Epoxy					x										
2	Fiber Flex		x				2010[1]									
3	Cable Indent Flex		x				2010[2]		Test Data Available for Sequence 1 Through 5							
4	Cable Flex		x				2010[3]									
5	Cable Handling		x				2060[4]									
6	Termination Evaluation		x				2030[5]				x	x			x	
7	Insertion Losses				x		34	x	x		x	x			x	
8	Tensile Individual		x				3010[6]				x	x			x	x
9	Tensile Individual @ −55°C		x				3010[6]				x	x			x	x
10	Maintenance Aging			x			1344 2002	x	x	Alternating		x			x	
11	Durability			x			500 Cy		x			x			x	x
12	Temperature Life @ 125°C			x			1 000 hr	x		x				x	x	
13	Humidity			x			1344 1002[11]		x	x				x	x	x
14	Salt Spray Unmated			x			1344 1001B		x	x		x			x	
15	Vibration			x				x	x	x			x		x	x
16	Vibration Gunfire						MCAIR	x	x	x			x		x	x
17	Mechanical Shock			x			1344 2004	x	x			x	x		x	x
18	Thermal Shock			x			1344 1003A		x	x				x	x	
19	Sand and Dust			x			202 110A	x		x		x			x	
20	Harness Flex @ Connector −40°C		x				2010[7]	x				x			x	x
21	Harness Flex @ Connector 55°C		x				2010[7]	x				x			x	x
22	Tensile Integrated Harness		x				3010[8]		x			x			x	x

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cable was then flexed 360° around an 0.125 inch mandrel with the indent located on the outside of the bend. One test cycle was required.

(4) Cable Flex - Sequence 4

(a) Rationale - Cable portions near connectors or routed across door hinges are subject to repeated flexing. This test determines the cables' resistance to cyclic flexing. The results represent prior testing; deviations from DoD-STD-1678 reflect an in-house flex test procedure.

(b) Procedure - DoD-STD-1678, Method 2010, Procedure II was modified to use a 4.6 kg test mass and a bend mandrel radius of 5 times the cable outside diameter. One thousand cycles were required.

(5) Cable Handling - Sequence 5

(a) Rationale - System malfunction will often be corrected by replacing the "black box" to which the interconnect cable is attached. The cable is subject to the unmating of the connector, pushing aside for box removal and replacement, and for remating the cable to the box. This test simulates the handling the cable undergoes during normal aircraft life. Since no standard test was available, a procedure simulating the handling procedure was created.

(b) Procedure - DoD-STD-1678, Method 2060, Procedure I, modified to use the Figure 9 apparatus. Prior to Step 2, the specimen was indented 1 inch from the attachment point by the Sequence 3 method. Step 2 rotation was 360° and return at 18 RPM. The cable connector was fixed to the rotational arm which is 4 inches long (8 inches in diameter). The cable twisted during rotation. The opposite cable end of the cable was clamped 8 inches from the rotating arm on the same center line. At the same time that the connector end of cable was rotating, the clamped end moved horizontally 4 inches back and forth at a speed of 20 inches per second. A cycle was defined as 360° rotation and return. Five thousand cycles were required.

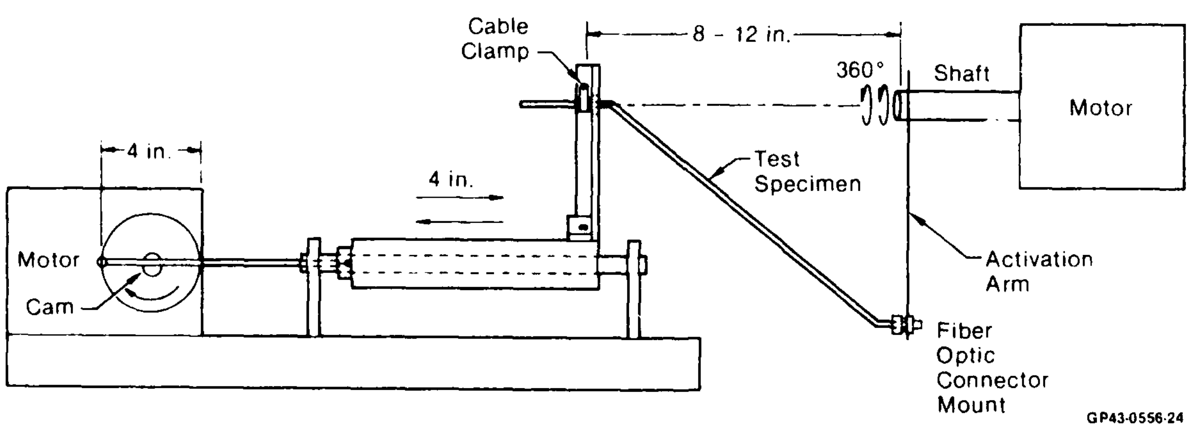

Figure 9. Fiber Optics Cable Handling Test Setup

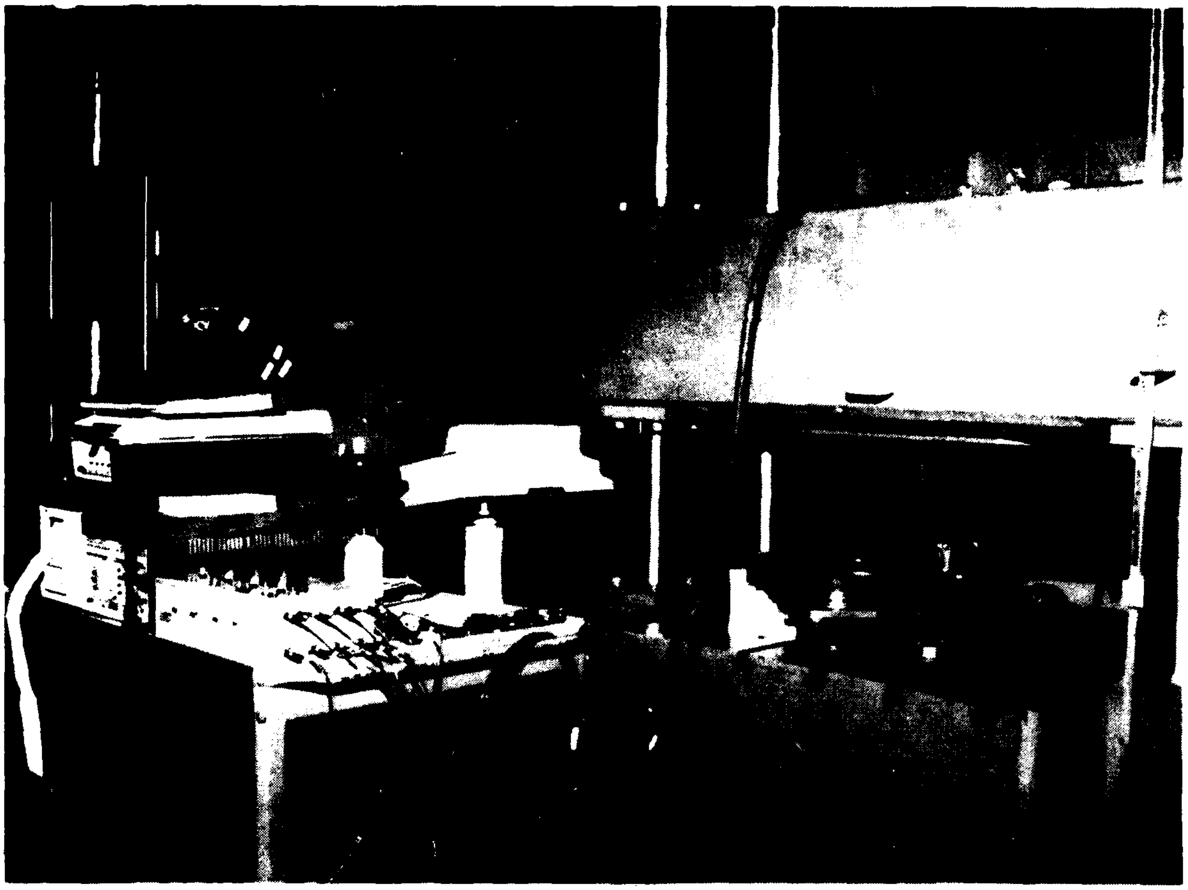

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Figure 23. Integrated Harness Tensile Test Setup

TABLE 11. EPOTEK #377 EPOXY HYDROLYTIC STABILITY DATA

	Control Sample		160°F, 95% R.H. Sample	
	Resistance (ohms)	Hardness (Shore D)	Resistance (ohms)	Hardness (Shore D)
Initial	100×10^{11}	15	100×10^{11}	18
After 120 Days	100×10^{11}	20	2.4×10^{11}	20

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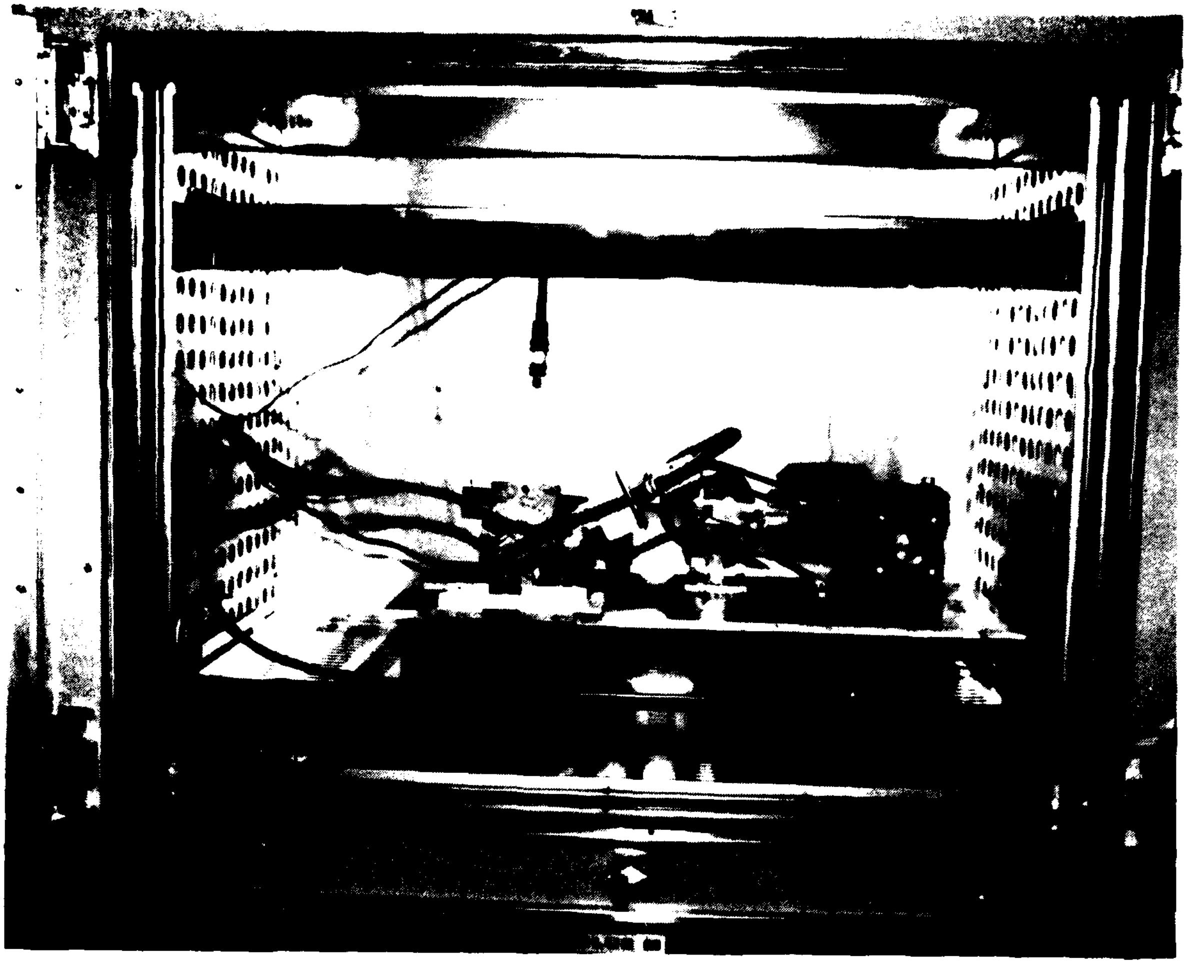

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Figure 22. Flex Test Setup

a. <u>Epoxy Hydrolytic Stability - Sequence 1</u> - This test established that Epotek #377, a two part epoxy, is hydrolytically stable. After the 120 day exposure to 95% relative humidity at 160°F, the hardness did not decrease more than 10%, and the electrical resistance was greater than 1 x 10^8 ohms. The data is shown in Table 11.

b. <u>Fiber Flex - Sequence 2</u> - Three samples each of company "X8" and company "X3" fiber, with the buffer coating, were wrapped 360° around a 0.125 inch mandrel without fiber breakage.

c. <u>Cable Indent/Flex - Sequence 3</u> - The company "X8" cable successfully passed a 360° wrap around an 0.125 inch mandrel following indentation with a 1.1 kg weight. Ten samples were tested without fiber breakage. The company "X3" cable was considered to have met this requirement in the Sequence 5 test.

d. <u>Cable Flex - Sequence 4</u> - The company "X8" cable successfully passed 1000 cycles of cyclic flexing without fiber breakage. Comapny "X3" cable was considered to have met this requirement in the Sequence 5 test.

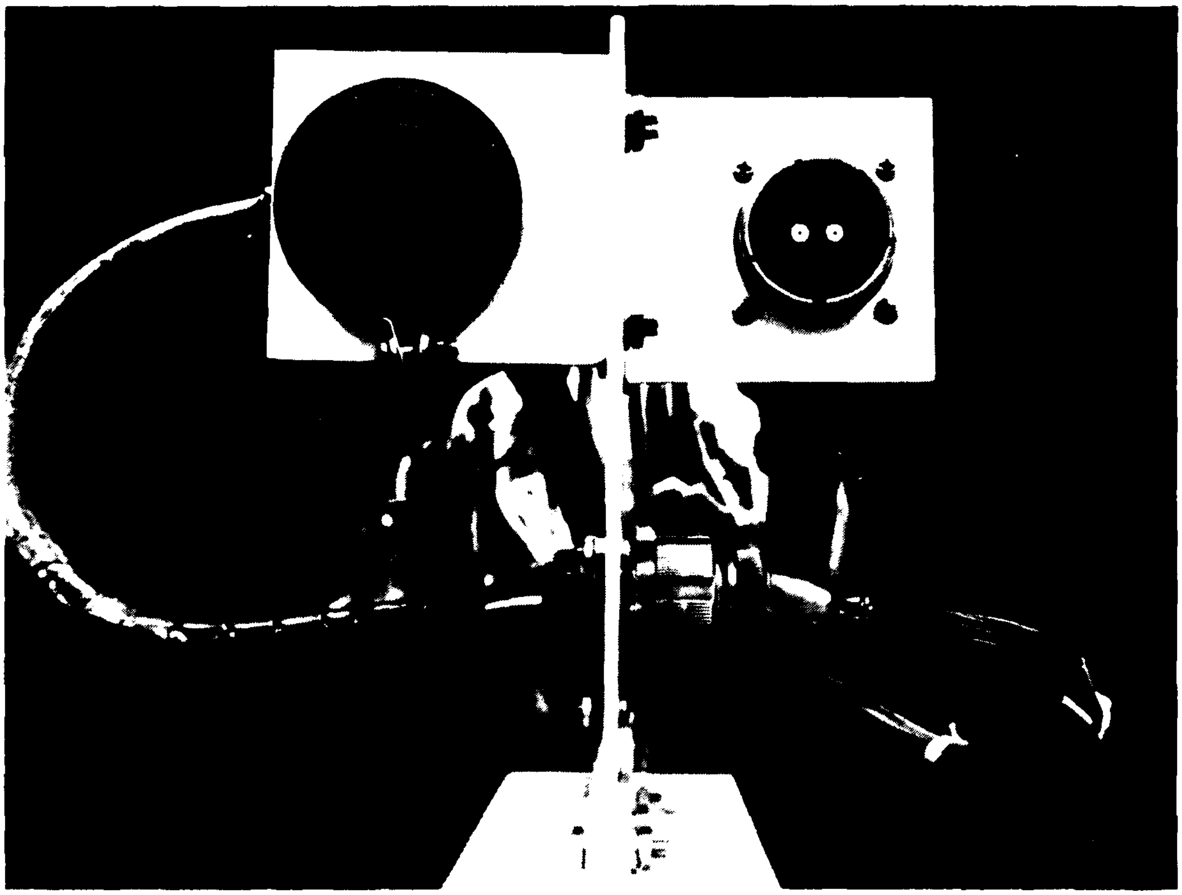

Figure 21. Specimens A and B Mounted for Sand and Dust Test GP43-0556-36

(a) Rationale - This test was performed to determine if the interconnect system in an integrated harness configuration could meet the requirements imposed upon an all-electrical wiring harness for use in a military aircraft.

(b) Procedure - Specimen B was mounted in the tensile test machine. The cables on each side of the mated MIL-C-38999 connectors were individually subjected to the test per DoD-STD-1678, Method 3010, Procedure II, modified to test a complete harness/connector specimen instead of a single cable. The load was applied at a 1 inch per minute travel rate until a 100 pound load was recorded. Travel stopped for 5 minutes and then continued until the load was again 100 pounds. Following a 1 minute travel hold, the load was again brought back to 100 pounds. Initial and final OPT measurements and continuous measurements were made on each cable throughout the test. Figure 23 is a photograph of the integrated harness tensile test set-up.

6. TEST RESULTS

NOTE: All results are considered acceptable unless otherwise indicated on the individual test data tabulations.

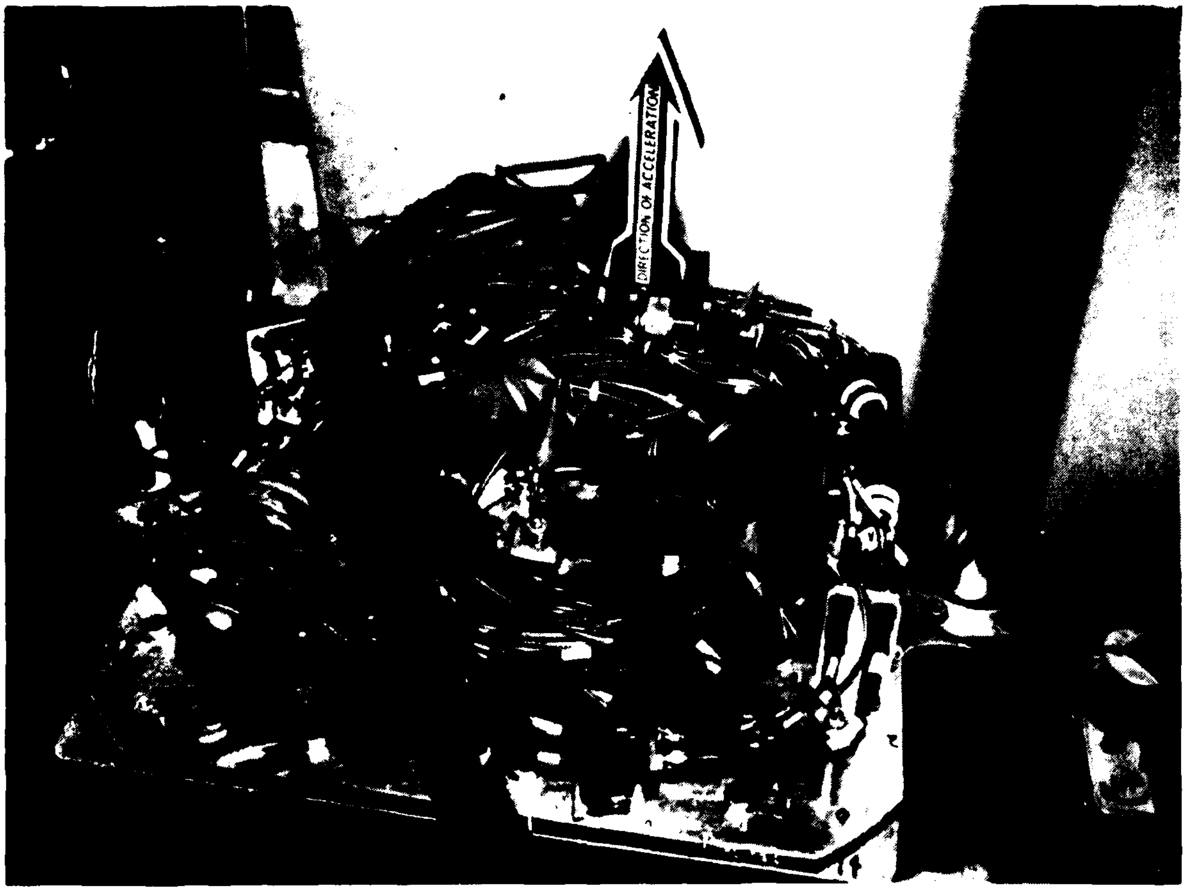

Figure 20. Direction of Mechanical Shock GP43-0556-35

(b) Procedure - Specimen A was mounted on the flex machine. A plate with the connector mounted on it was positioned such that the top of the strain relief was at the centerline of the flex arm. The open harness construction side of the cable was flexed. The cable was put under 15 to 20 pounds tension, 9 inches from the connector, by a compression spring. It was conditioned in -40°C ambient temperature for 1 hour and 45 minutes. Cyclic flexing was performed per DoD-STD-1678 Method 2010 Procedure II modified to allow the harness to flex at the connector rather than over a specified mandrel. The flex arm was rotated 120° (60° each side of center) at 30 cycles per minute for 200 cycles. Each cycle consisted of moving the arm from the vertical position to 60° right of vertical; then back through vertical; to 60° left of vertical; and back to vertical. The specimen was then conditioned for 2 hours at an ambient temperature of 55°C and the flex test was repeated. OPT measurements were made with the laboratory source and the continuous monitor sources before and after the flex tests at room temperature. Continuous measurements were made throughout the flex test. Figure 22 is a photograph of the flex test set up.

(21) Harness Flex at Connector, 55°C - Sequence 21
See Sequence 20.

(22) Tensile, Integrated Harness - Sequence 22

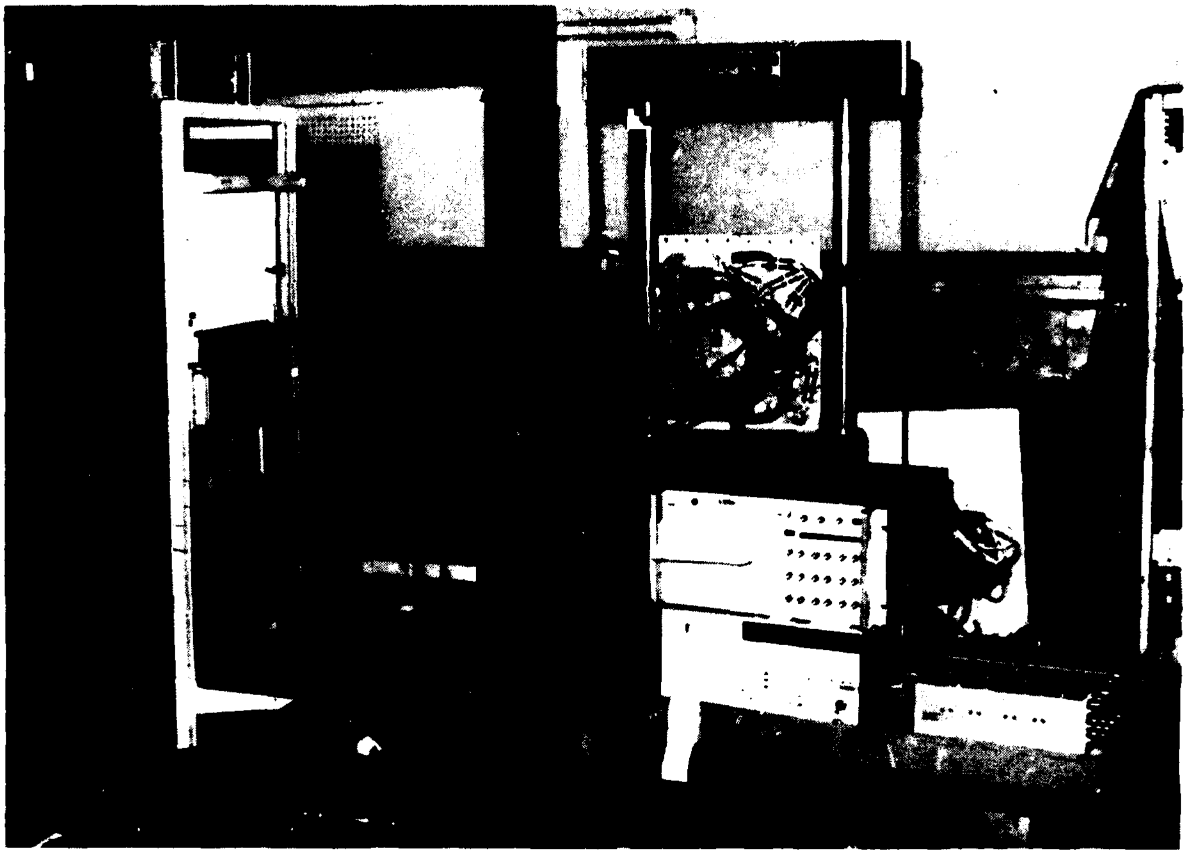

Figure 18. Connectors Mounted Vertically on Mechanical Shock Machine GP43-0556-33

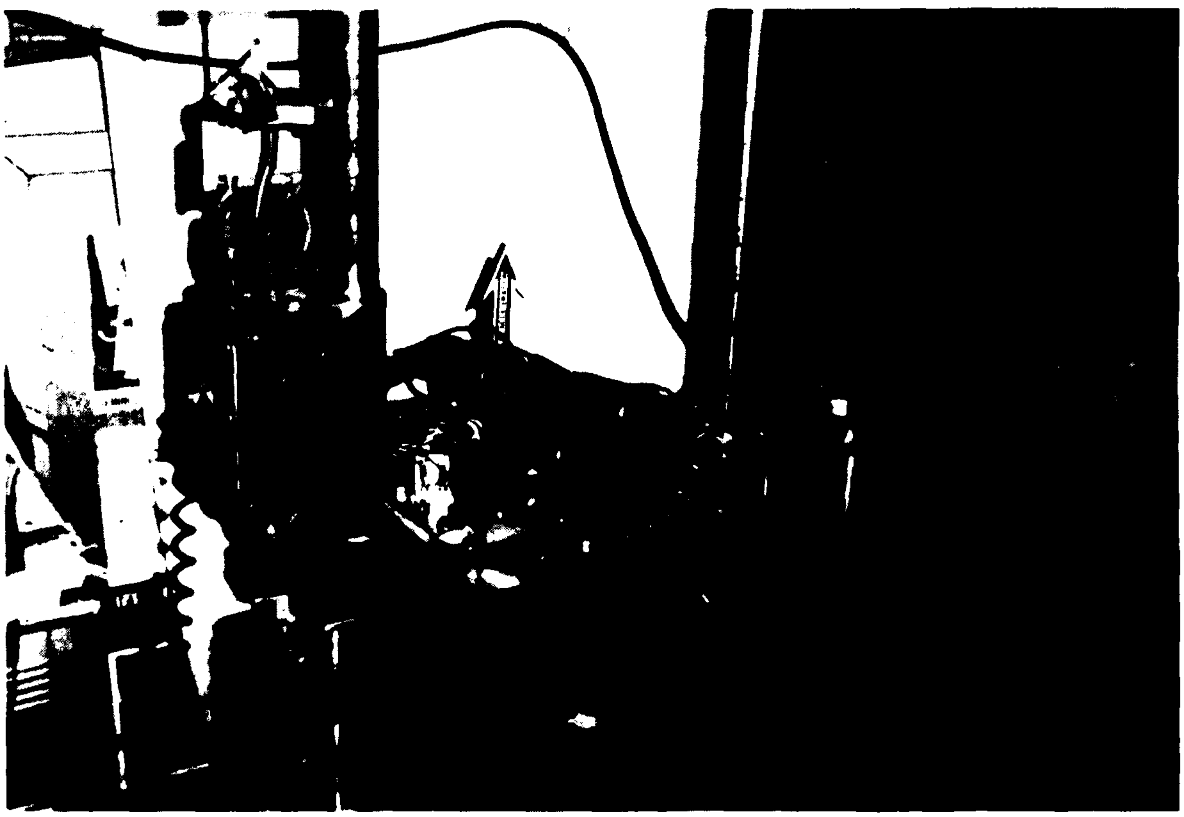

Figure 19. Connectors Mounted Horizontally on Mechanical Shock Machine GP43-0556-34

(b) Procedure - The vibration test setup was placed on the mechanical shock machine, with the specimens mounted on the vibration plate. Initial OPT measurements were made with the jumpers connected.

A mechanical shock test was performed on the specimens in six directions per MIL-STD-1344, Method 2004, Condition D, with continuous measurement of the detector output voltage of each fiber optics circuit. Final OPT measurements were made with and without jumpers at the conclusion of the test. Figures 18, 19, and 20 are photographs of the mechanical shock test set-up.

(18) Thermal Shock - Sequence 18

(a) Rationale - This test was performed to determine if the interconnect assembly could withstand the rapid, extreme changes in temperature that are encountered in a military aircraft.

(b) Procedure - Specimen B was mounted on a mandrel with weights hung on the cables on each side of the MIL-C-38999 connector. Specimen C was coiled and hung on the mandrel rack. Initial OPT measurements were made after the specimens were mounted. This configuration was subjected to a thermal shock test per MIL-STD-1344, Method 1003, Condition A (5 cycles, -55°C to 85°C). Each cycle consisted of the specimens being subjected to one hour of $-55^{+0°}_{-5°}$C ambient and one hour of $85^{+5°}_{-1°}$C ambient with a maximum of 5 minutes transfer time between environments. After the 10 hour test (5 continuous cycles), the specimens were allowed to stabilize for 24 hours at room temperature. Final OPT measurements were made with the specimens in the test configuration.

(19) Sand and Dust - Sequence 19

(a) Rationale - This test was performed to determine if the interconnect system, in either the mated or unmated condition, would be susceptible to damage from blowing sand and dust.

(b) Procedure - Specimen A was set up for the sand and dust test in the mated configuration, and the connectors on specimen B were unmated. Initial OPT measurements were made on specimen A after mounting, and on specimen B before mounting. The cable ends opposite the MIL-STD-38999 connectors (SMA connectors) were coiled and enclosed in a plastic bag for protection. This configuration was shipped to Dayton T. Brown Research Laboratories where light was transmitted through each circuit to verify continuity. The mounting stand was placed in the dust chamber with the unmated specimen B connectors perpendicular to the air stream. The MIL-STD-2020 Method 110 Condition A Sand and Dust Test was then performed. At the conclusion of the test, the continuity was verified, and the specimens were returned to MCAIR. Final OPT measurements were made on specimen A before removal from the mounting stand. Specimen B was unmounted and cleaned before final OPT measurements were made. Figure 21 is a photograph of the sand and dust test set-up.

(20) Harness Flex at Connector, -40°C - Sequence 20

(a) Rationale - This test was performed to determine if the interconnect system, in a harness configuration, would be susceptible to damage due to flexure at low or high temperature.

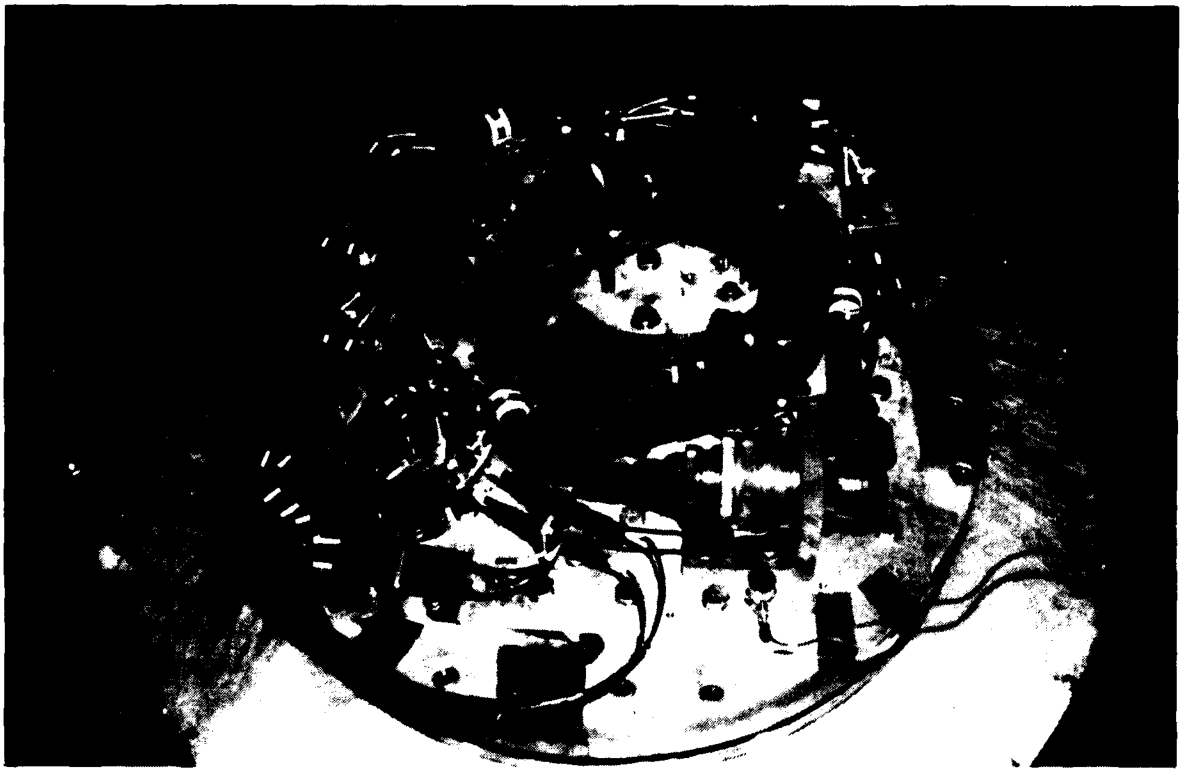

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Figure 16. Specimens A, B, and C Mounted on Vibration Plate

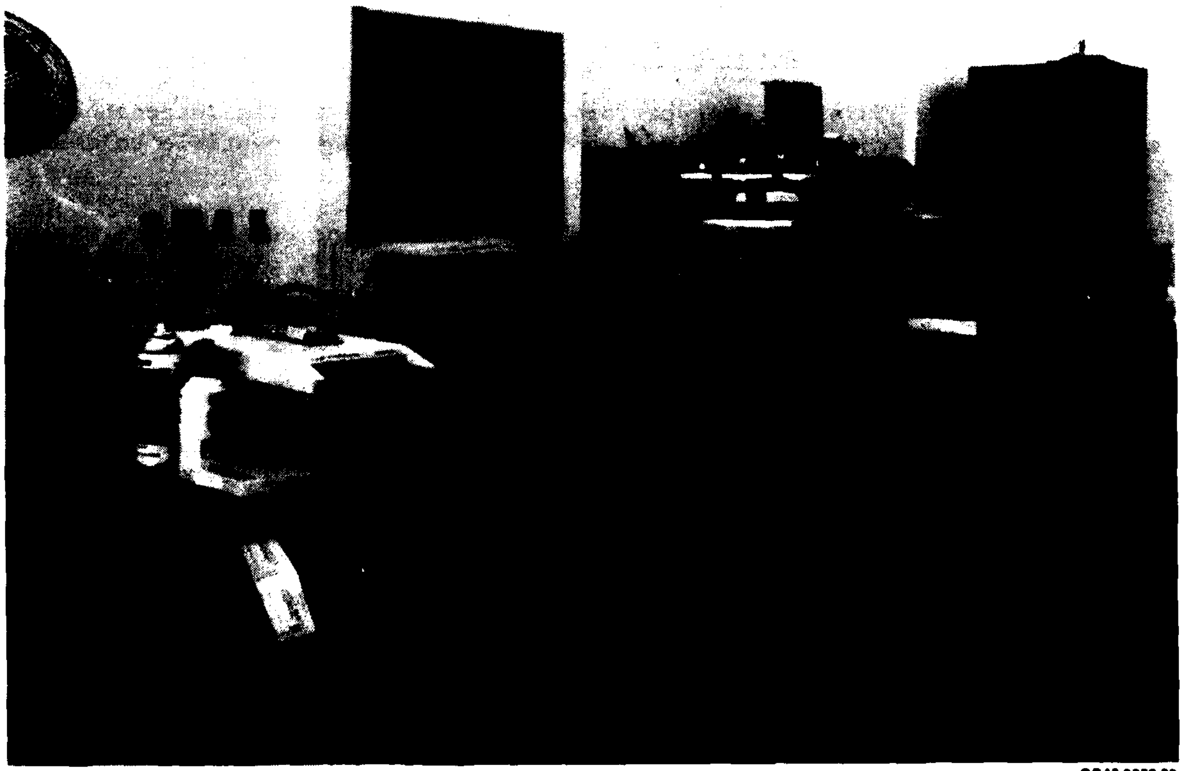

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Figure 17. Vibration Plate Mounted on Vibration Machine

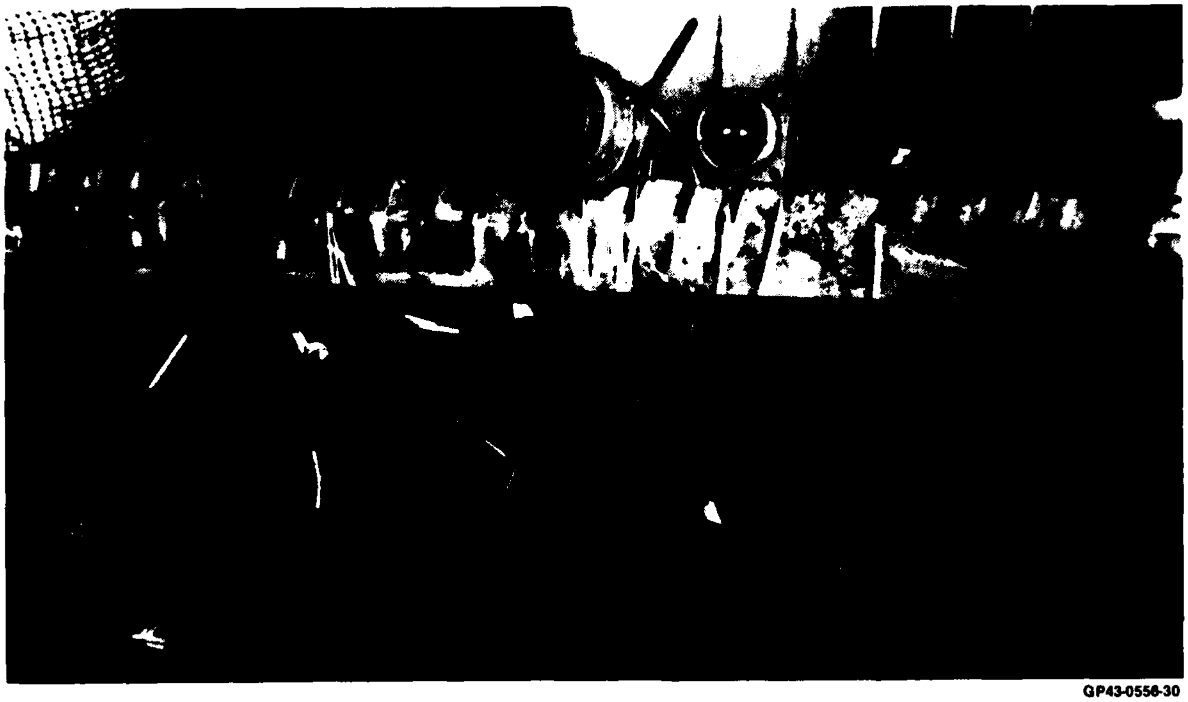
GP43-0556-30

Figure 15. Salt Spray Test Setup

(15) Vibration - Sequence 15

(a) Rationale - This test was performed to determine if the interconnect system could meet the vibration requirements.

(b) Procedure - Specimens A, B and C were mounted on a 16 x 16 x 1/2 inch aluminum vibration plate per MIL-W-5088. The specimen connectors were mounted on 1/2 inch angles which were bolted to the vibration plate. The cables were coiled and clamped to the plate, and the SMA connector ends of the cables were terminated into adapters mounted on small angles which, in turn, were mounted on the plates. Initial OPT measurements were made with and without jumpers. The continuous measurement equipment was then connected and continuous measurements were made throughout the vibration test.

The vibration plate was mounted on a vibration machine head and vibrated along the vertical axis per MIL-STD-1344, Method 2006, Series II. The specimens were then vibrated along the vertical axis, to aircraft gunfire requirements per MDC Report A3376, Section 4.2.8. Final OPT measurements were made with and without jumpers. Figures 16 and 17 are photographs of the vibration test set-up.

(16) Vibration, Gunfire - Sequence 16

See Sequence 15.

(17) Mechanical Shock - Sequence 17

(a) Rationale - This test was performed to determine if the interconnect system could meet the mechanical shock requirements.

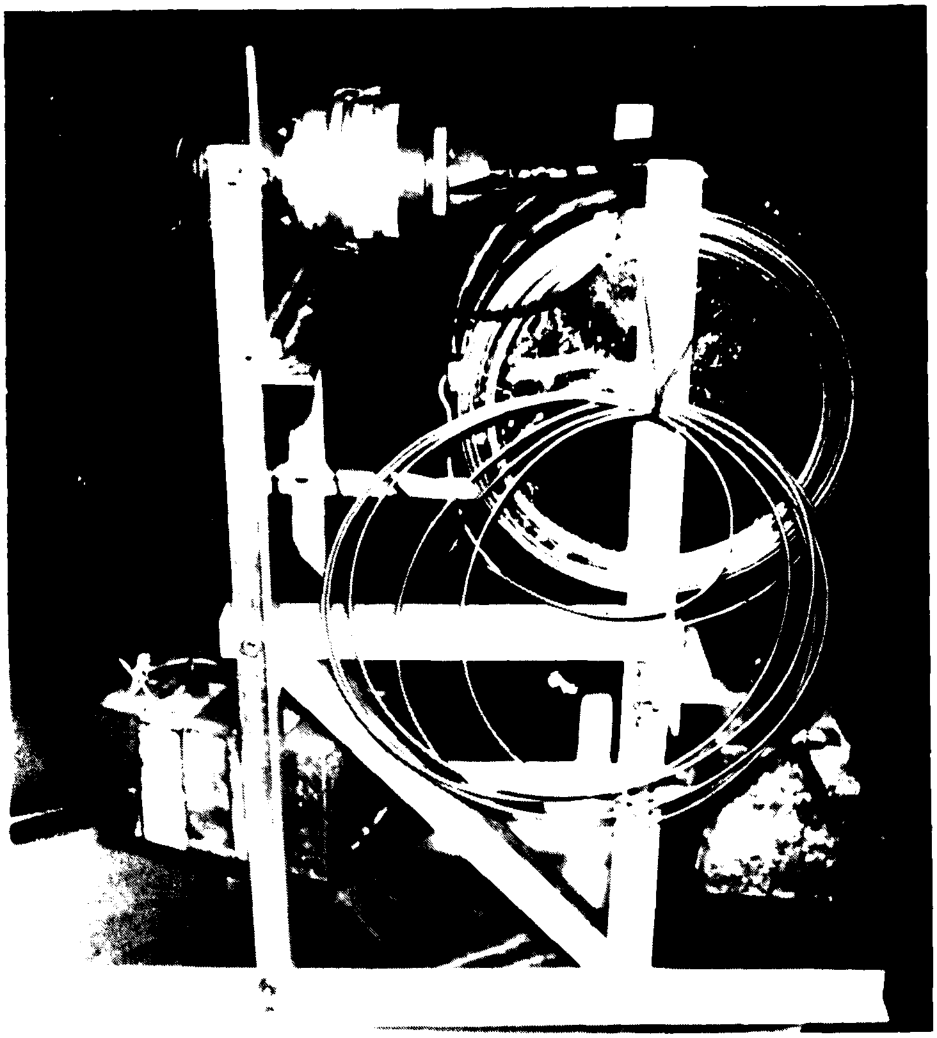
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Figure 14. Humidity Test Setup

(14) Salt Spray, Unmated - Sequence 14

(a) Rationale - This test was performed to determine if the interconnect system could meet the salt spray requirements considered important in flight qualification for high performance military aircraft.

(b) Procedure - Initial OPT measurements were made on harness specimens B and C. Specimen B was unmated and tied to a salt spray rack as shown in Figure 15. The connector halves were positioned horizontally, and the SMA terminations were covered. Specimen C was coiled, and its SMA terminations were covered. These two specimens were exposed to salt spray per MIL-STD-1344, Method 1001, test Condition B (5% salt solution, 48 hours). After the salt spray test, the specimens were gently washed in running tap water and dried in a circulating air oven at a temperature of 38°C ± 5° for 12 hours. OPT measurements were then repeated.

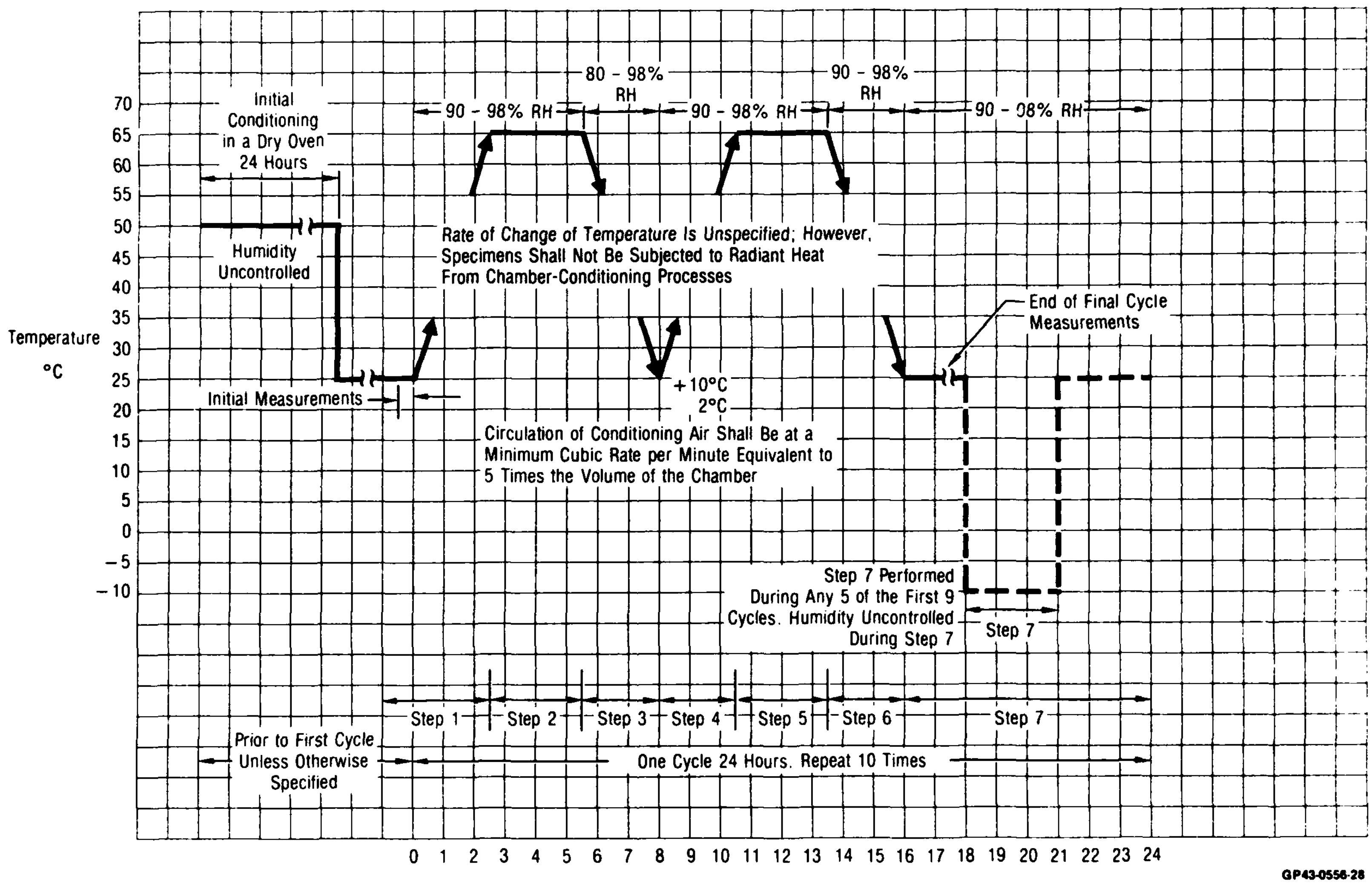

Figure 13. Graphical Representation of Humidity Test

Figure 12. Tensile Pull - Split Connector Clamp and Mounting

GP43-0556-27

(13) Humidity - Sequence 13

(a) Rationale - This test was performed to determine if the interconnect system could meet the humidity requirements considered important in flight qualification for high performance military aircraft.

(b) Procedure - Specimens B and C were exposed to the humidity test per MIL-STD-1344, Method 1002, Type II (10 cycles). The specimen B wall mount receptacle was mounted on an angle bracket, and the cable was wound on a 6.5 inch diameter mandrel with weights hung on the cable. Specimen C was coiled and hung with no weights attached. Both specimens had the SMA connector terminated ends outside the chamber. OPT measurements were made before and after the jumpers were connected. The continuous measuring equipment was attached. Figure 13 is a graphical representation of the ten cycle humidity and temperature vs time plot that was followed. After the test and 24 hours of room temperature stabilization, OPT measurements were repeated with and without jumpers. Figure 14 is a picture of the humidity test set-up.

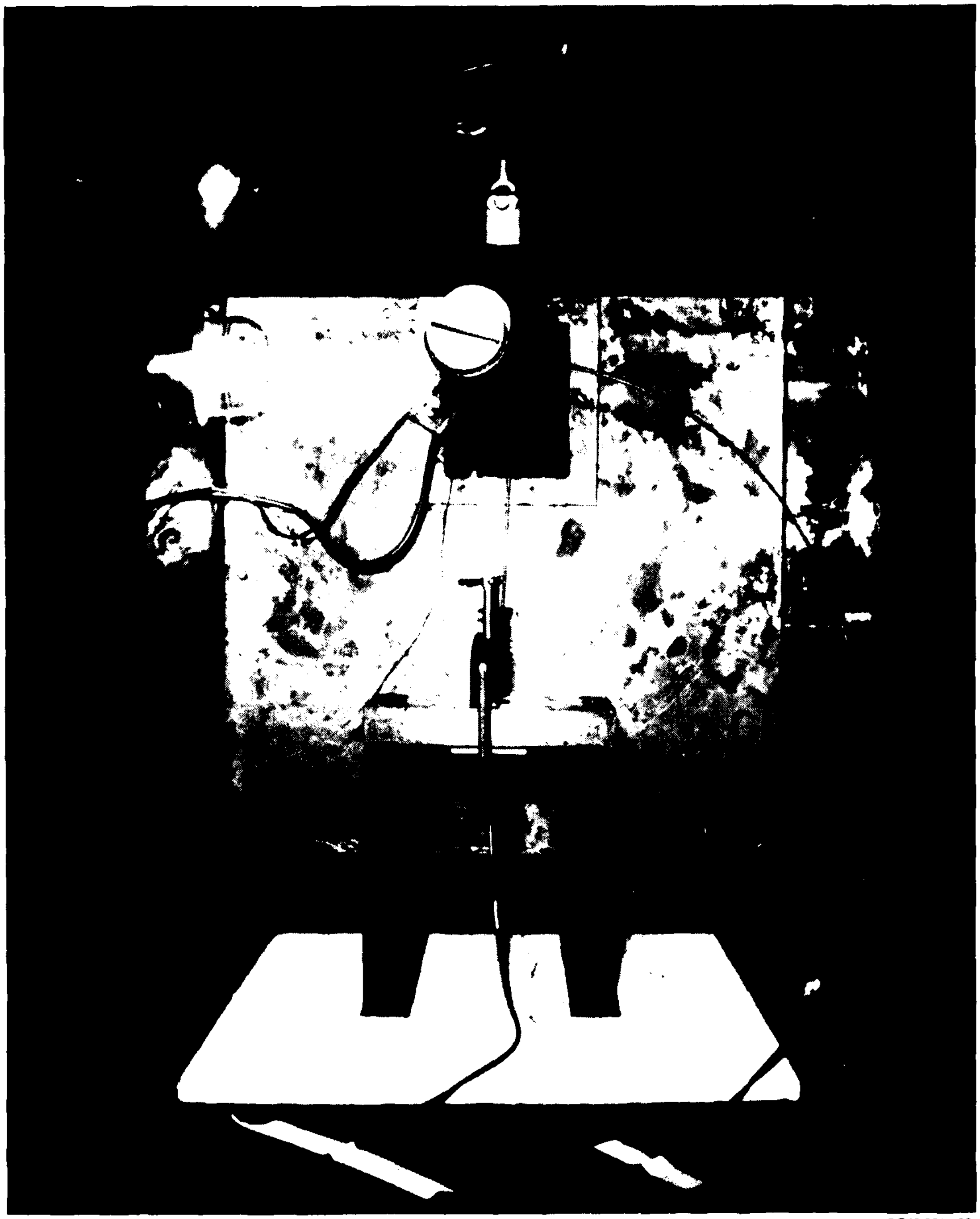

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Figure 11. Tensile Pull in Chamber

(8) Tensile, Individual, Room Temperature - Sequence 8

(a) Rationale - Measurements were made to determine the mechanical reliability of the termination under tensile pull forces at room temperature.

(b) Procedure - The test was performed per DoD-STD-1678, Method 3010, Procedure II. The tensile load was applied at a rate of one inch per minute. The OPT was monitored continuously during the load application.

(9) Tensile, Individual, -55°C - Sequence 9

(a) Rationale - Measurements were made to determine the mechanical reliability of the termination under tensile pull forces at -55°C.

(b) Procedure - The test was performed per DOD-STD-1678, Method 3010, Procedure II as described in Sequence 8. Figures 11 and 12 are pictures of the tensile test set-up.

(10) Maintenance Aging - Sequence 10

(a) Rationale - The Maintanence Aging test was performed to determine if the mated pair interconnect system was able to meet the requirements of the MIL-C-38999 electrical connector specification.

(b) Procedure - The test was performed per MIL-STD-1344, Method 2002. The fiber optics contacts were removed and inserted following every 50 matings and unmatings of the durability test, for a total of 10 Maintenance Aging cycles. OPT measurements were made at the conclusion of each Maintenance Aging cycle.

(11) Durability - Sequence 11

(a) Rationale - The Durability test was performed to determine if the mated pair interconnect system would meet the requirements of the MIL-C-38999 electrical connector specification.

(b) Procedure - The test was performed per MIL-C-38999, Section 4.7.7 for 500 cycles. The forces required to insert the pins and sockets were recorded. The connector was mated and OPT measurements taken. At the conclusion of the test, the insertion forces were again measured and OPT measurements taken.

(12) Temperature Life - Sequence 12

(a) Rationale - The Temperature Life test was performed to determine if the cable-contact system was capable of withstanding prolonged exposure to the high temperatures encountered in a fighter aircraft.

(b) Procedure - Specimens A and C were subjected to a 1000 hour temperature life test at 125 ± 5°C ambient. Specimen A was mounted on a 6 ± 0.25 inch diameter mandrel with 15 pound weights hung on the cables on each side of the MIL-C-38999 connector. The cable ends opposite the connector were brought out of the chamber. Jumper cables were attached to these ends to provide continuous monitoring of the MIL-C-38999 fiber optics contacts. Specimen C was coiled with the SMA connectors capped and hung in the chamber. After the 1000 hour test and 24 hours of room temperature stabilization, OPT measurements were made on all cables with the jumper cables disconnected.

(6) Termination Evaluation - Sequence 6

(a) Rationale - The assembly of five fiber optics contact terminations provided familiarization with termination procedures. During the fabrication, the susceptibility to bench handling shocks was assessed. Installation and removal of contacts from the connector insert was evaluated to identify any differences from the procedures used for electrical contact terminations. Since no standard test was available, a procedure simulating bench handling shock was created.

(b) Procedure - The cables were subjected to termination impact tests. Each pin and each socket end of each fiber optics cable was attached to a steel leaf and impacted against a steel plate. The cable was taped to the leaf eight inches from the pin or socket, and the leaf was raised six inches above the impact surface and then released to allow the pin or socket to strike the impact plate. Final OPT measurements were made after six impacts of each contact. Figure 10 is a drawing of the termination evaluation test set-up.

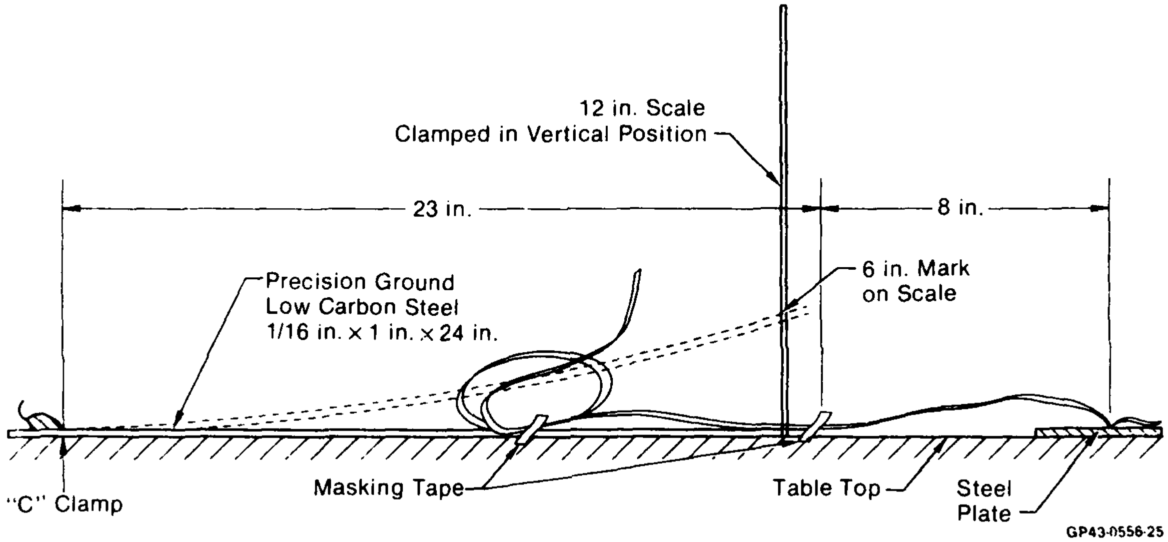

Figure 10. Termination Evaluation Test

(7) Insertion Losses - Sequence 7

(a) Rationale - Measurements were made on sixteen cables before and after the installation of the MIL-C-38999 pin and socket contacts in order to determine the insertion loss of the pins and sockets. EIA insertion loss test procedure FOTP-34 had not been completed, so the procedure used followed the FOTP-34 proposals at that time.

(b) Procedure - Each cable was assembled with an SMA connector on each end. OPT measurements were made on each cable. Each cable was cut in half. The connections to the source and detector were not disturbed. A pin contact was installed on the free end of one segment, and a socket contact was installed on the free end of the other segment. The pin and socket were then mated in a MIL-C-38999 connector and Optical Power Throughput (OPT) measurements were made. The difference in losses before and after the pin-socket installation is defined as the insertion loss of the contact pair.

e. Cable Handling - Sequence 5 - The test results indicate that the cables tested are capable of withstanding repeated mating and unmating operations due to "black box" servicing conditions. The test was passed with a Sequence 3-type indentation in the cable near the connector. The test data is listed in Table 12.

TABLE 12. CABLE HANDLING TEST DATA

Cable Source	Travel Rate Horizontal (in/sec)	Travel Rate Rotational (RPM)	Cycles Performed	Optical Change
X8	20	18	5,500	0
X3	20	18	5,500	0

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f. Termination Evaluation - Sequence 6 - This test resulted in refined termination procedures, which were incorporated into the fabrication specification. The insertion/removal experience that was gained produced a recommendation for the use of insertion tools.

The bench handling susceptibility data is shown in Table 13.

TABLE 13. BENCH HANDLING SUSCEPTIBILITY DATA

Cable Number	Pin and Socket Mated Without Connector		Pin and Socket in Mated Connector	
	Initial (dBu)	Final (dBu)	Initial (dBu)	Final (dBu)
X1A-X1D	11.9	10.3	10.6	10.2
X2A-X2D	11.8	12.8	12.0	12.7
X3A-X3D	11.3	10.1	11.0	9.1
X4A-X4D	8.4	8.8	9.1	9.1
X5A-X5D	12.4	12.4	12.3	12.2

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g. Insertion Losses - Sequence 7 - This test resulted in improved epoxy procedures for the assembly of the cable-contact system. The losses attributed to the insertion of the pin-socket contact pair are shown in Table 14.

h. Tensile, Individual, Room Temperature - Sequence 8

See Sequence 9.

i. Tensile, Individual, -55°C - Sequence 9 - This test indicated that the fiber optics terminations could withstand tensile pull forces at least as great as those that can be withstood by 26AWG electrical wire.

TABLE 14. INSERTION LOSS DATA

Lead Identification	Optical Power Transmission (OPT) Lead With SMA's Only (dBu)	Lead With SMA's and Pin-Socket Inserted (dBu)	Lead With SMA's and Pin-Socket in MIL-C-38999 Connector (dBu)	Insertion Loss (dB)
B1B1 - B2B1	11.7	11.1[1]	11.6[1] 10.2[2]	1.5
C1B1 - C2B1	11.9	10.8	10.6	1.3
C1P1 - C2P1	13.8	10.4	10.8	2.0
B1P1 - B2P1	13.2	10.5	10.7	2.5
B1B2 - B2B2	11.7	10.4	10.1	1.6
C1B2 - C2B2	12.3	11.5	12.8	—
C1P2 - C2P2	13.1	11.5	12.7	0.4
B1P2 - B2P2	14.3	10.7	10.4	3.9
B1B3 - B2B3	11.8	10.1	9.9	1.9
C1B3 - C2B3	12.7	8.1	10.5	2.2
C1P3 - C2P3	12.6	10.3	11.2	1.4
B1P3 - B2P3	13.2	10.5	11.1	2.1
B1B4 - B2B4	12.0	9.5	9.8	2.2
C1B4 - C2B4	13.2	11.4	10.8	2.4
C1P4 - C2P4	13.3	11.2[1]	1.3[1] 11.9[3]	1.4
B1P4 - B2P4	13.3	11.0	10.9	2.4
B Control	13.0			
P Control	12.7			
X1A - X1D	13.0		11.2	1.8
X2A - X2D	13.2		11.1	2.1
X3A - X3D	13.6		11.4	2.2
X4A - X4D	13.0		11.5	1.5
X5A - X5D	14.1	12.4	12.4	1.9

Notes:
(1) Protruding fiber
(2) Replaced SMA connector
(3) Replaced "NN" pin

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The tensile pull data for the individual samples are shown in Table 15, and a summary of the break forces required to destroy the cable-termination system is shown in Table 16. Figures 24 and 25 are a graphical representation of the Sequence 8 and 9 test results.

j. Maintenance Aging - Sequence 10 - The insertion force data is shown in Table 17. See Sequence 11 for additional data.

k. Durability - Sequence 11 - The OPT and the insertion force data for the individual specimens, a summary of change in losses, and a summary of the physical condition of the interconnect system are shown in Tables 18, 19, and 20.

l. Temperature Life - Sequence 12 - Initial-final measurement data is shown in Table 21, continuous monitor plots are shown in Figure 26, and a summary of the test data is shown in Table 22.

TABLE 15. INDIVIDUAL TENSILE DATA

Identification Number	Length of Sample	Ambient Temperature	Maximum Tension (lb)	Elongation (in.)	Comments
B2B3	11.25	R.T.	37.5	0.642	
B2P3	11.25	R.T.	21.0	0.685	
C2B3	11.25	R.T.	65.8	0.722	
C2P3	11.25	R.T.	38.5	2.069	
X1B	16.00	R.T.	32.0	1.006	Socket Separated
X1C	16.00	R.T.	111.0	1.812	Socket Separated
X2B	16.00	R.T.	61.0	1.321	Epoxy Bond Failed
X2C	16.00	R.T.	12.5	0.656	Epoxy Bond Failed
X3B	16.00	R.T.	84.5	0.709	Socket Separated
X3C	16.00	R.T.	166.5	1.218	Epoxy and Strength Member Failed
X4B	16.00	R.T.	38.5	0.600	Strength Member Failed
X4C	16.00	R.T.	75.0	0.792	Epoxy and Strength Member Failed
X5B	16.00	R.T.	66.5	1.420	Connector Separated
X5C	16.00	R.T.	94.0	1.763	Strength Member Failed
B1B3	11.25	−55°C	56.5	0.430	
B1P3	11.25	−55°C	100.2	1.037	
C1B3	11.25	−55°C	94.7	0.666	
C1P3	11.25	−55°C	44.7	0.630	

Note: (1) Data lost - tape malfunction

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TABLE 16. BREAK FORCE SUMMARY

Connector	Cable	Break Force (lb)		
		Preliminary @ R.T.	@ R.T.	@ −55°C
"DD"	"X8"	32, 111, 67, 94	21	100
"DD"	"X3"	85, 167	32	57
"NN"	"X8"	61, 13*	39	45
"NN"	"X3"	39, 75	66	95

*Poor epoxy adhesion

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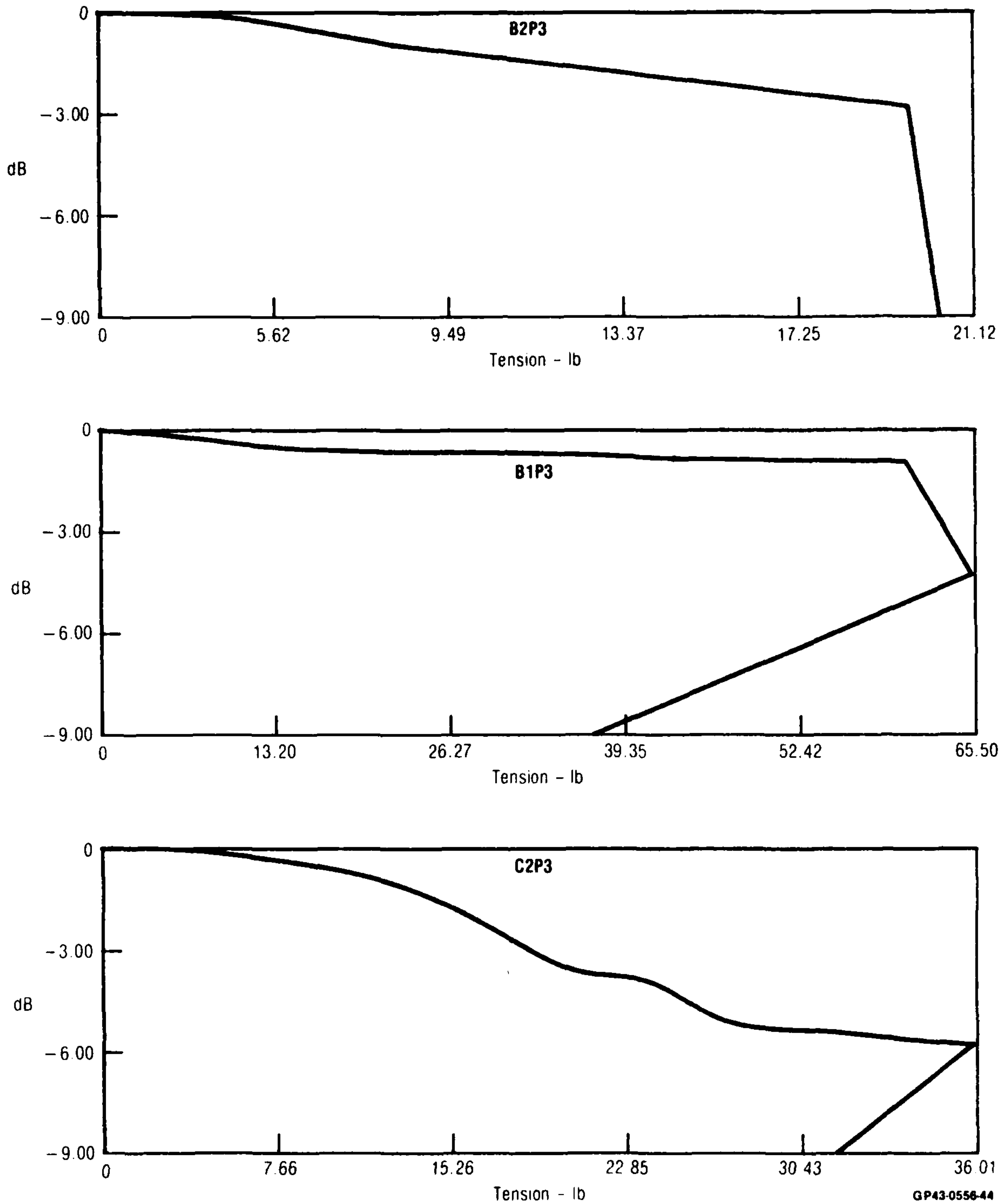

Figure 24. Tensile Test Data, Individual; Room Temperature

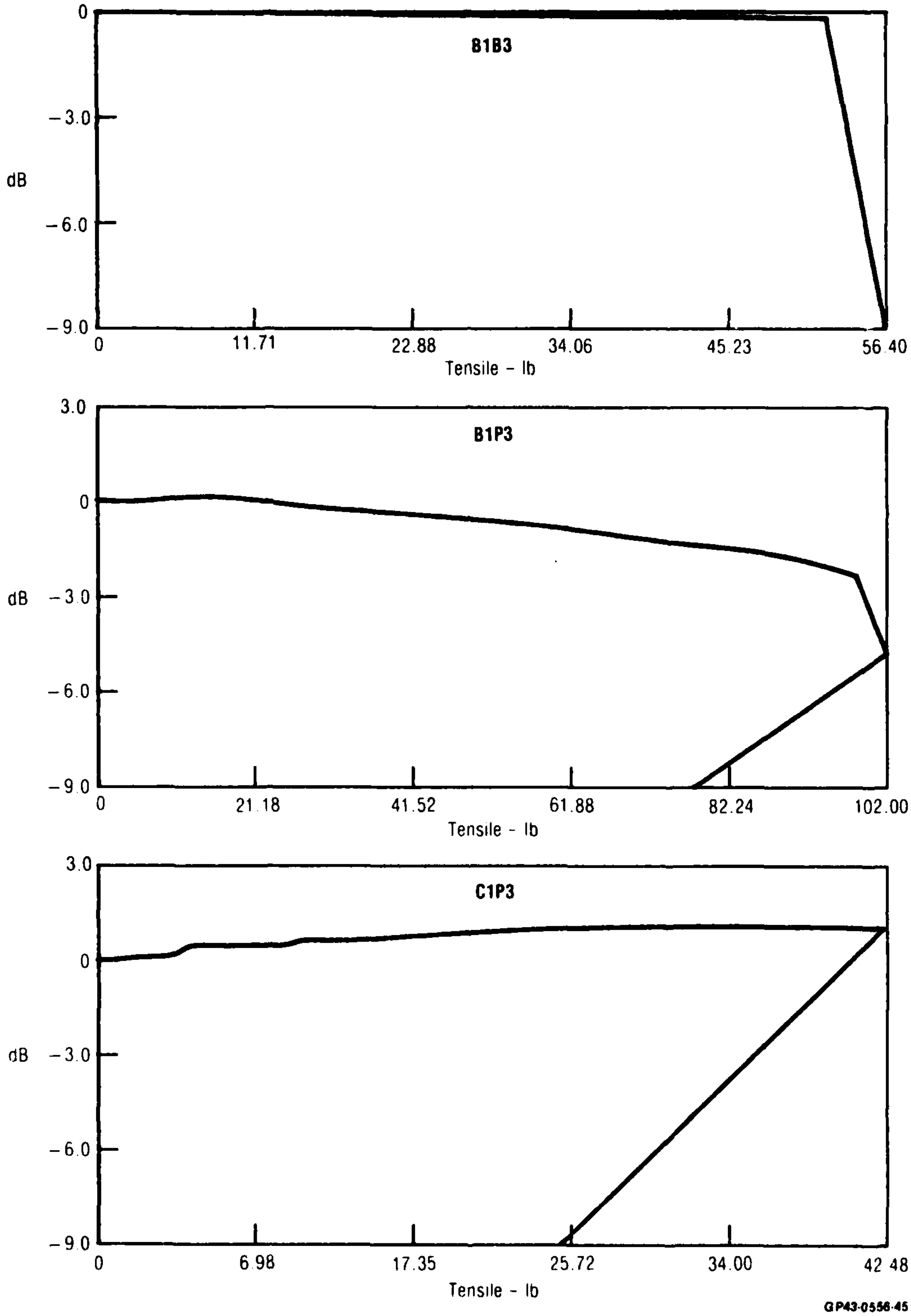

Figure 25. Tensile Test Data, Individual
−55°C

TABLE 17. MAINTENANCE AGING TEST RESULTS

Procedure - MIL-C-38999 Termination Insertion Force
Requirement - Less Than 20 lb

Specimen	Test Circuit		Force to Insert (lb) First Insertion	Force to Insert (lb) Tenth Insertion
Lanyard	BB-Y	Pin	4.0	2.5
	BP-X	Pin	3.3	2.7
	CB-V	Pin	5.0	2.8
	CP-AA	Pin	4.5	3.0
	BB-Y	Socket	4.5	3.0
	BP-X	Socket	8.0	*
	CB-V	Socket	5.0	3.0
	CP-AA	Socket	7.0	4.0

*Alignment sleeve could not be removed

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m. Humidity - Sequence 13 - Initial-final measurement data is shown in Table 23, a summary of the test data is shown in Table 24, and continuous monitor plots are shown in Figure 27.

n. Salt Spray, Unmated, Sequence 14 - The pre- and post-salt spray test OPT measurements are shown in Table 25. The two circuits with the company "NN" pins/sockets failed. The OPT measurements are shown before and after these circuits were repaired. A second salt spray test was run, and the data is also reported below. This test was performed on the replacement pins/sockets after they had been through vibration, mechanical shock, thermal shock, sand and dust, and integrated harness tensile tests. The only failure resulting from the salt spray test was an SMA connector with a protruding fiber (pistoning) on the C2B2 cable. A summary of the change in losses for the test specimens is shown in Table 26.

o. Vibration - Sequence 15 - OPT data measured with the UDT #S550 meter, and the OPT continuous measurement data, are shown in Table 27. The continuous measurement data figures are each comprised of three curves: 3-hour sinusoidal, gunfire random, and gunfire sinusoidal. These results are given in graphical form in Figures 28 through 36. Optical power transmission was not significantly changed. There were no discontinuities of 1 microsecond or greater, no loosening of the connectors at the mating point or of the backshells. A summary of the changes in losses for the test specimens is shown in Table 28.

TABLE 18. MAINTENANCE AGING AND DURABILITY DATA

Identification Number	Initial OPT (dBu)	Insertion Force Pin (lb)	Insertion Force Socket (lb)	2nd OPT (dBu)	3rd OPT (dBu)	4th OPT (dBu)	5th OPT (dBu)	6th OPT (dBu)	7th OPT (dBu)	8th OPT (dBu)	9th OPT (dBu)	Insertion Force Pin (lb)	Insertion Force Socket (lb)	10th OPT (dBu)	Final OPT (dBu)	After Booting[4] (dBu)	After Repair[7] (dBu)
"V"																	
C1B2	11.7	5.0	5.0	11.2	11.4	11.8	11.9	11.5	12.8	12.1	12.1	2.75	3.0	13.0	12.2	11.0	10.7
C2B2																	
"X"																7.9	
B1P2	11.4	3.5	8.0	12.0	10.8[1]	12.1[2]	9.6[3]	9.9	10.9	10.2	10.2	2.63	—	9.9	10.8		11.4
B2P2																9.4[5]	
"Y"																	
B1B2	7.6	4.0	4.5	8.2[1]	4.6	7.6	4.2	4.5	5.2	3.9	5.4	2.50	3.0	5.5	3.6	−16.0[6]	9.6
B2B2																	
"AA"																	
C1P2	11.3	4.5	7.0	11.1	12.1	12.2	12.4	11.9	11.7	11.9	11.8	3.00	4.0	11.1	11.7	11.3	11.5
C2P2																	
"X"																	
B1B1	10.9	7.8	5.5									8.30	3.5		11.2		10.4
B2B1																	
"V"																	
B1P1	5.6	7.0	5.3									4.50	3.8		4.6		7.8
B2P1				Removed and Inserted 10 Times. No Mating and Unmating Between Removals.													
"AA"																	
C1B1	10.1	2.3	5.3									3.80	4.8		7.5		10.4
C2B1																	
"Y"																	
C1P1	8.0	4.5	6.0									7.00	4.8		8.5		8.8
C2P1																	

Notes
(1) Spacer in guide sleeve fell out. Guide sleeve replaced
(2) Sleeve stayed in connector when removed. New sleeve
(3) Sleeve stayed in connector, new sleeve. This socket was not removed for the remaining test
(4) Readings after cable rebooting by manufacturing
(5) Spacer had folded edge, second reading is with new spacer
(6) Fiber broken in B2B2 (socket) during booting by manufacturing
(7) Readings after replacement of B2B2, spacer in B2P2 and B2P1

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TABLE 19. MAINTENANCE AGING AND DURABILITY TEST RESULTS
MIL-C-38999 10 Insert-Removals and 500 Mate-Unmates

Specimen	Test Circuit	Change in Losses (dB)										
		Number of Durability Cycles (Mate/Unmate)(1)										
		0	50	100	150	200	250	300	350	400	450	500
Lanyard	BP-X	0	−0.6	+0.6	−0.7(2)	+1.8(3)	+1.5	+0.5	+1.2	+1.2	+1.5	+0.6
	BB-Y	0	−0.6(2)	+3.0	0	+3.4	+3.1	+2.4	+1.7	+1.7	+2.1	+4.0
	CB-V	0	+0.5	+0.3	−0.1	+0.2	+0.2	−0.8	−0.4	−0.4	−1.3	−0.5
	CP-AA	0	+0.2	−0.8	−0.9	−1.1	−0.6	−0.4	−0.6	−0.5	+0.2	−0.4
		Number of Maintenance Aging Cycles (Insert/Remove)										
				0		10						
Non-Lanyard	BB-X			0		−0.3						
	BP-Y			0		+1.2						
	CB-AA			0		−0.1						
	CP-Y			0		+0.3						

Notes
(1) Measurement after each 50 mate/unmate cycles plus one contact removal-insertion
(2) Spacer fell out of alignment sleeve - replaced with new sleeve
(3) Alignment sleeve could not be removed. Test continued without maintenance aging steps.

CB and CP Acceptable

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TABLE 20. INTERCONNECT PHYSICAL CONDITION
MIL-C-38999 10 Removal-Insertions/500 Mate-Unmates

Specimen	Test Circuit		Optical Continuity	Inner Jacket Attached to Contact	Strength Member Attached to Contact	Outer Jacket Flush With Contact
Lanyard	BP-X	Pin	X	X	X	
	BB-Y	Pin	X	X	X	
	CB-V	Pin	X	X	X	X
	CP-AA	Pin	X	X	X	X
	BP-X	Socket	X			
	BB-Y	Socket	X	X		
	CB-V	Socket	X	X	X	
	CP-AA	Socket	X	X		

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TABLE 21. TEMPERATURE LIFE TEST DATA

Identification Number	Optical Power Transmission (OPT) Initial[1] (dBu)	Initial With Jumpers[2] (dBu)	Final With Jumpers[2] (dBu)	Final[1] (dBu)	Change[3] (dB)
B1B1; B2B1	9.5	12.4	13.3	11.4	+ 1.9
B1P1; B2P1	9.7	15.2	13.9	7.6	− 2.1
C1B1; C2B1	10.9	12.3	12.2	11.2	+ 0.3
C1P1; C2P1	10.6	15.8	14.9	9.4	− 1.2
Control	12.2			12.6	− 0.4

Notes:
(1) Before mounting on mandrel with lab source and UDT S550
(2) After mounting on mandrel with a continuous monitor source and UDT S550. The source was not disconnected until final readings were made.
(3) Initial to final

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TABLE 22. TEMPERATURE LIFE TEST RESULTS

Specimen	Test Circuit	Change in Losses (dB) At R.T.	Start of 125°C	After 1,000 hr @ 125°C
Non-Lanyard	BB-X	0	− 0.8	− 0.8
	BP-V	0	− 1.8	− 1.8
	CB-AA	0	− 0.1	+ 0.3
	CP-Y	0	− 0.6	− 0.6

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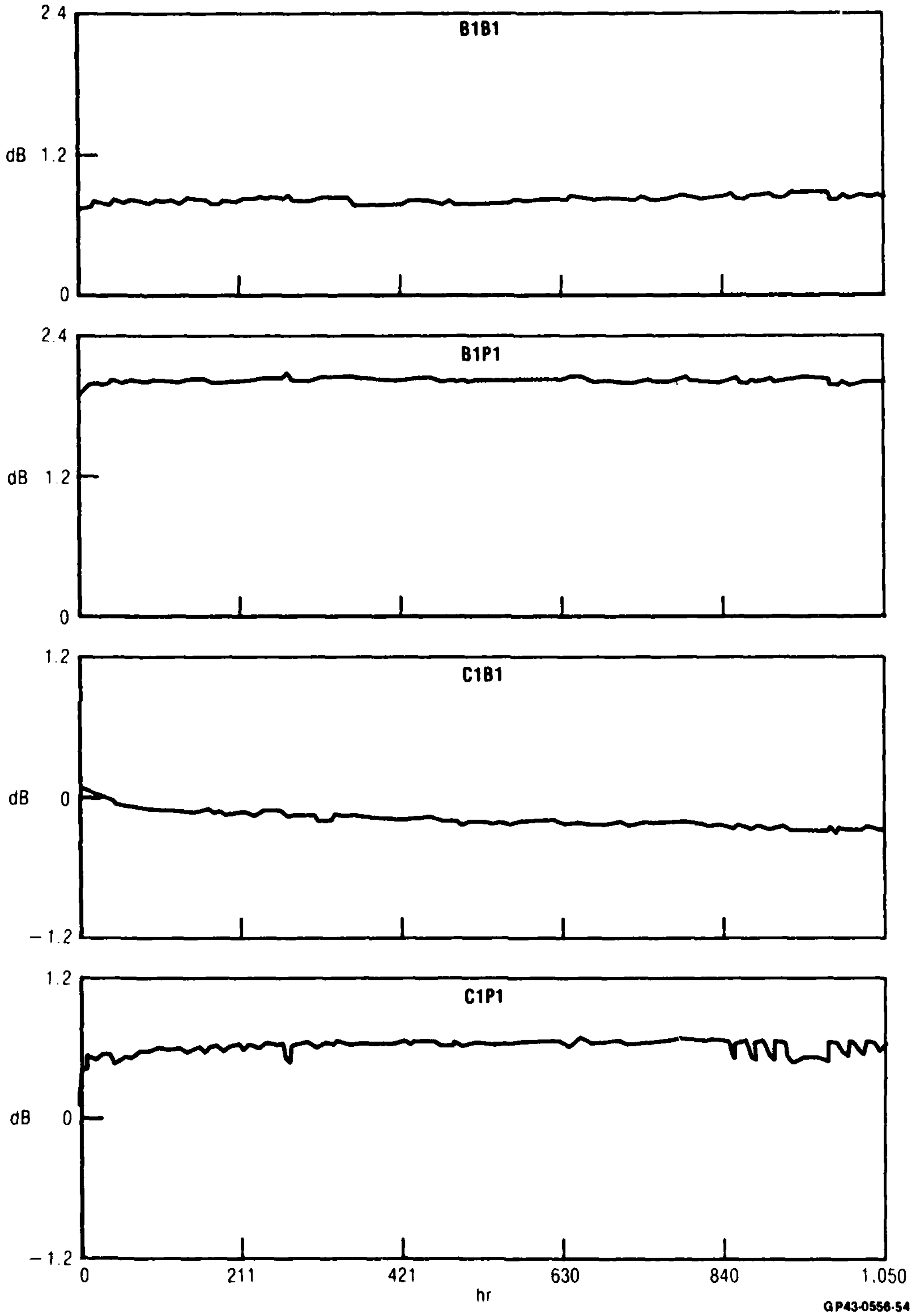

Figure 26. Temperature Life Test Data

TABLE 23. HUMIDITY INITIAL-FINAL MEASUREMENT DATA

Identification Number	Initial Test Without Jumpers(1) (dBu)	Initial Test With Jumpers(2) (dBu)	Final Test With Jumpers(2) (dBu)	Final Test Without Jumpers(1) (dBu)
B1B2 - B2B2	9.5	11.8	12.7	10.5
B1P2 - B2P2	12.4	12.6	11.9	12.6
C1B2 - C2B2	9.8	13.9	14.2	12.0
C1P2 - C2P2	10.6	13.7	13.6	11.5
Control B	12.6	15.3	5.3	6.0(3)

Notes:
(1) *Laboratory Source and UDT S550 Detector*
(2) Continuous Monitor Source and UDT S550 Detector. (Source was not turned off or disconnected between initial and final readings.)
(3) Fiber broke in one SMA connector

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TABLE 24. HUMIDITY CYCLING TEST RESULTS

MIL-C-38999, MIL-STD-1344 Method 1002II 10 Cycles 95% R.H.

Specimen	Test Circuit	Change in Losses (dB)
Lanyard	BB-Y	– 1.0
	BP-X	+ 0.2
	CB-V	– 2.2
	CP-AA	– 0.9

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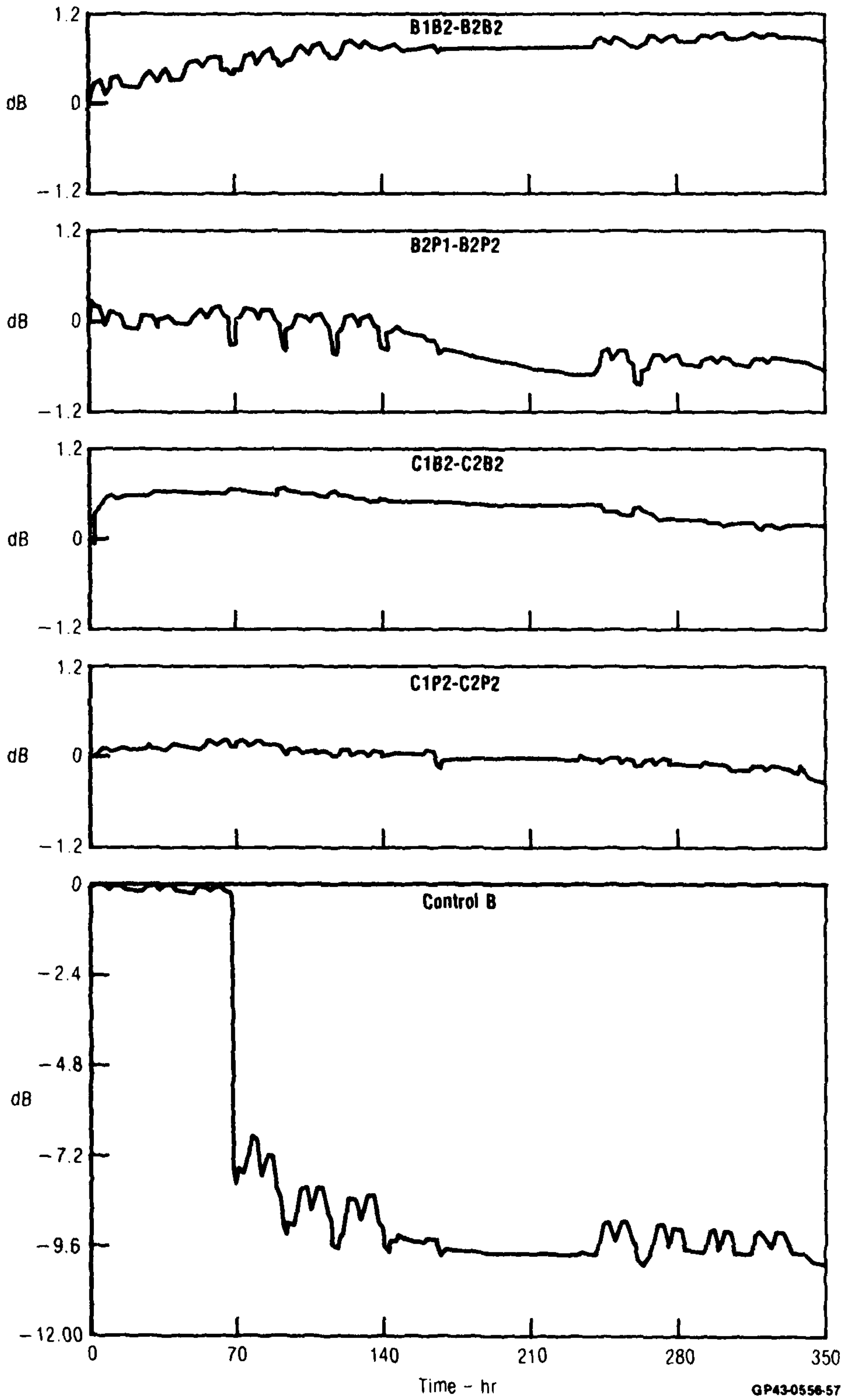

Figure 27. Humidity Test Data

TABLE 25. SALT SPRAY TEST DATA

Identification Number	Initial OPT (dBu)	Final OPT (dBu)	OPT After Cleaning (dBu)	OPT After Repair[1] (dBu)
B1B2 - B2B2	11.1	10.8	10.8	11.4
B1P2 - B2P2	12.2	12.9	12.6	11.4
C1B2 - C2B2	10.9	4.2	6.5	9.3
C1P2 - C2P2	12.1	4.8	6.0	12.9
P Control	13.9	13.4		

Note: (1) C1B2 and C2P2 replaced

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TABLE 26. SALT SPRAY TEST RESULTS
MIL-C-38999, MIL-STD-1344/1001B 5%, 48 Hr

Specimen	Test Circuit	Change in Losses (dB)	
		Mated After Water Rinse	Mated After Solvent Cleaning
Lanyard	BB-Y	+ 0.3	+ 1.1
	BP-X	− 0.7	− 0.2
	CB-V	+ 1.2	+ 0.5
	CP-AA	− 0.4	0

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TABLE 27. VIBRATION OPT DATA

Identification Number	Test 1 Initial OPT Without Jumpers(1) (dBu)	2 Initial OPT With Jumpers(1) (dBu)	3 Initial Vibration OPT With Jumpers(2) (dBu)	4 Post Vibration OPT With Jumpers(2) (dBu)	5 Post Vibration OPT Without Jumpers(2) (dBu)
B1B1 - B2B1	10.4	2.9	10.3	10.3	10.6
B1P1 - B2P1	7.8	1.7	6.4	7.9	6.6
C1B1 - C2B1	10.4	4.1	9.0	8.5	10.3
C1P1 - C2P1	8.8	7.4	12.3	12.7	9.8
B1B2 - B2B2	9.9	8.3	15.5	15.3	9.9
B1P2 - B2P2	12.0	6.0	7.2	7.4	12.4
C1B2 - C2B2	10.6	4.7	11.1	11.0	9.9
C1P2 - C2P2	11.5	6.8	12.6	13.4	12.9
Control P	13.6	10.5	14.7	14.8	13.9

Notes

(1) Laboratory Controlled Source and UDT S550 Detector

(2) Continuous Sources and UDT S550 detector

Continuous Sources were not disconnected between Test 3 and 4

Continuous Sources were not disconnected between Test 6 and 7

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p. Vibration, Gunfire - Sequence 16

See Sequence 15.

q. Mechanical Shock - Sequence 17 - The OPT measurement data is shown in Table 29. The data taken from a UDT #S550 meter and from the continuous monitor detector data from the oscillograms is shown in Table 30. This data shows the maximum dB change, duration of change, start and finish dB level, and peak-to-peak dB ripple. A summary of the changes in losses is shown in Table 31.

r. Thermal Shock - Sequence 18 - The initial and final OPT data is shown in Table 32. A summary of the changes in losses is shown in Table 33. The SMA connector on cable C1B2 developed a pistoning fiber during the test. The control cable exhibited a 1.8 dB loss that was eliminated by straightening the cable.

s. Sand and Dust - Sequence 19 - Initial and final OPT data is shown in Table 34. A summary of the test data is shown in Table 35.

t. Harness Flex at Connector, -40°C - Sequence 20 - Initial and final OPT data is shown in Table 36. Continuous monitor data is shown graphically in Figures 37 and 38. A summary of the test data is shown in Table 37.

TABLE 36. FLEX TEST DATA

Identification	Initial Data		Post Data		Ambient Temperature (°C)
	(dBu)(1)	(dBu)(2)	(dBu)(2)	(dBu)(1)	
B1B1 - B2B1	10.5	16.3	16.1	11.7	+ 55
B1P1 - B2P1	8.8	14.2	15.3	9.3	+ 55
C1B1 - C2B1	11.1	15.5	15.9	11.4	+ 55
C1P1 - C2P1	6.5	14.2	14.6	8.4	+ 55
B1B1 - B2B1	11.2	15.8	15.5	10.8	− 40
B1P1 - B2P1	8.2	14.5	14.4	8.4	− 40
C1B1 - C2B1	11.0	15.7	14.2	9.9	− 40
C1P1 - C2P1	8.2	14.0	13.5	6.9	− 40

Notes:
(1) UDT S550 Power Meter Reading with Laboratory Source
(2) UDT S550 Power Meter Reading with Continuous Monitor Sources

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TABLE 37. FLEX TEST RESULTS
DOD-STD-1678 Method 2010 II Modified*

Specimen	Test Circuit	Change in Losses (dB)	
		− 40°C Exposure	+ 55°C Exposure
Non-Lanyard	BB-X	+ 0.3	+ 0.2
	BP-V	+ 0.1	− 1.1
	CB-AA	+ 1.5	− 0.4
	CP-Y	+ 0.5	− 0.4

*— Free flex, no mandrel
— 120° flex
— Connector mounted on centerline of flex arm
— 200 cycles
— 15 lb tension load

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TABLE 34. SAND AND DUST TEST DATA

Identification	Initial Data (dBu)	Post Data (dBu)(1)	(dBu)(2)	(dBu)(3)
Specimen A (Non-Lanyard)				
B1B1 - B2B1	10.3	11.6		
B1P1 - B2P1	7.6	7.8		
C1B1 - C2B1	10.7	11.0		
C1P1 - C2P1	8.5	8.0		
Specimen B				
B1B2 - B2B2	10.5		4.4	10.0
B1P2 - B2P2	9.7		6.0	11.1
C1B2 - C2B2	11.3		10.2	11.3
C1P2 - C2P2	11.0		8.9	9.7

Notes:
(1) Specimen A was mated during test. These readings were made before unmating.
(2) Specimen B was unmated during test. SMA connectors were cleaned with Freon and wiped with a tissue. MIL-C-38999 connector was cleaned by blowing with dry air.
(3) MIL-C-38999 connector was cleaned with Freon and wiped with a tissue.

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TABLE 35. SAND AND DUST TEST RESULTS
MIL-C-38999, MIL-STD-202 Method 110A

Specimen	Test Circuit	Change In Loss (dB) After Mated Exposure	After Unmated Exposure: Dry Air Clean Before Mating	After Unmated Exposure: Solvent Clean Before Mating
Non-Lanyard	BB-X	−1.3		
	BP-V	−0.2		
	CB-AA	−0.3		
	CP-Y	+0.5		
Lanyard	BB-Y		+6.1	+0.5
	BP-X		+3.7	−1.4
	CB-V		+1.1	0
	CP-AA		+2.1	+1.3

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TABLE 31. MECHANICAL SHOCK TEST RESULTS

MIL-C-38999, MIL-STD-1344 Method 2004D

Specimen	Test Circuit	Change in Losses (dB)
Non-Lanyard	BB-X	+ 0.3
	BP-V	− 1.4
	CB-AA	+ 0.5
	CP-Y	+ 0.5
Lanyard	BB-Y	− 0.1
	BP-X	+ 0.3
	CB-V	+ 1.2
	CP-AA	+ 1.2

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TABLE 32. THERMAL SHOCK DATA

Identification Number	Initial OPT Measurements (dBu)	Final OPT Measurements (dBu)
B1B2 - B2B2	10.1	10.4
B1P2 - B2P2	12.4	10.9
C1B2 - C2B2	8.7	10.3(1)
C1P2 - C2P2	11.0	11.4
Control P	13.4	11.6(2)

Notes:
(1) The SMA on the C1B2 cable had a protruding fiber (Pistoning).
(2) Cable was stretched and readings up to 14.0 dBu were achieved.

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TABLE 33. THERMAL SHOCK TEST RESULTS

MIL-C-38999, MIL-STD-1344 Method 1003A

Specimen	Test Circuit	Change in Losses (dB)
Lanyard	BB-Y	− 0.3
	BP-X	+ 1.5
	CB-V	− 1.6
	CP-AA	− 0.4

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TABLE 30. MECHANICAL SHOCK LOSS DATA

Drop Number	F.O. Identification Number	Direction 1 Level Change (dB)	Direction 1 Maximum Deflection (dB)	Direction 1 Time of Change (sec)	Direction 2 Level Change (dB)	Direction 2 Maximum Deflection (dB)	Direction 2 Time of Change (sec)	Direction 3 Level Change (dB)	Direction 3 Maximum Deflection (dB)	Direction 3 Time of Change (sec)	Direction 4 Level Change (dB)	Direction 4 Maximum Deflection (dB)	Direction 4 Time of Change (sec)	Direction 5 Level Change (sec)	Direction 5 Maximum Deflection (dB)	Direction 5 Time of Change (sec)	Direction 6 Level Change (dB)	Direction 6 Maximum Deflection (dB)	Direction 6 Time of Change (sec)
1	B1B1	+0.1400	1.531P-P	0.005	+0.090	+1.210 −0.760	0.001	—	0.69P-P	0.008	—	0.52P-P	0.012	0.04	+0.54	0.0300	—	+0.30 −0.90	0.024
	B1P1	−0.0007	0.339P-P	0.027	−0.050	0.236P-P	0.010	+0.08	0.25P-P	0.018	+0.04	0.49P-P	0.012	—	+0.32	0.0020	—	—	—
	C1B1	—	—	—	−0.310	0.110P-P	0.006	−0.060	—	—	—	−0.23	0.027	—	—	—	0.01	—	—
	C1P1	−0.009	0.480P-P	0.208	+0.056	0.140P-P	0.016	−0.060	+0.40	0.012	−0.04	+0.25 1.80	0.244	—	0.25P-P	0.0240	−0.15	+0.43 −0.10	0.016
	B1B2	—	−1.870	0.010	−0.010	−0.130	0.028	−0.070	+0.18	0.016	+0.05	−0.45	0.010	−0.02	+0.40	0.0050	+0.05	+0.20 −0.40	0.055
	B1P2	−0.0500	−0.410	0.037	+0.054	0.890P-P	0.085	—	+0.76	0.010	—	+0.29	0.002	—	—	—	—	0.40P-P	0.048
	C1B2	−0.0590	0.753P-P	0.033	—	0.410P-P	0.012	−0.180	0.84P-P	0.023	+0.18	0.65P-P	0.028	+0.22	0.60P-P	0.0330	—	0.60P-P	0.022
	C1P2	−0.1200	−1.100	0.122	+0.100	+0.120 −0.110	0.004	−1.230	+1.38	0.032	+0.19	+0.26 −0.67	0.100	−0.65	—	—	+0.14	+0.14	0.073
	Control P	−0.0100	+0.053	0.015	−0.030	0.100P-P	0.013	+0.020	0.19P-P	0.070	+0.02	0.13P-P	0.051	—	0.14P-P	0.0120	—	−0.80	0.005
2	B1B1	+0.0400	1.350P-P	0.006	+0.110	2.200P-P	0.001	—	0.53P-P	0.010	+0.01	1.09P-P	0.010	+0.01	+0.60	0.0040	—	+0.40 −0.80	0.024
	B1P1	—	—	—	−0.050	0.360P-P	0.024	—	0.24P-P	0.012	+0.04	0.48P-P	0.013	—	0.40P-P	0.0030	—	0.25P-P	0.018
	C1B1	—	—	—	—	0.470P-P	0.008	−0.050	—	—	+0.03	—	—	—	0.12P-P	0.0100	—	—	—
	C1P1	−0.0500	−0.580	0.244	−0.040	+0.230	0.015	−0.024	−0.30	0.009	+0.02	+0.16 −1.50	0.134	−0.03	0.25P-P	0.0330	−0.10	+0.50 −0.10	0.009
	B1B2	+0.1070	+1.220	0.009	—	−0.130	0.028	—	−2.12	0.010	+0.01	−0.70	0.007	—	+0.30	0.0490	—	+0.10 −0.40	0.055
	B1P2	−0.0500	+0.500	0.037	−0.120	1.410P-P	0.097	—	−0.20	0.009	0.03	−0.64	0.004	—	—	—	—	0.70P-P	0.049
	C1B2	+0.3300	+0.480	0.030	+0.040	+0.520	0.004	+0.090	0.64P-P	0.022	+0.09	0.42P-P	0.006	+0.30	0.80P-P	0.0370	—	0.60P-P	0.037
	C1P2	−0.5400	−2.000	0.122	—	+0.080 −1.080	0.030	+0.300	1.23P-P	0.030	−0.10	+0.13 −1.00	0.134	−0.20	0.95P-P	0.0430	—	+0.50	0.001
	Control P	+0.0500	−0.590	0.002	—	0.080P-P	0.024	+0.010	0.16P-P	0.045	+0.01	0.19P-P	0.048	—	0.14P-P	0.0040	—	−1.45	0.005
3	B1B1	+0.1000	1.330P-P	0.006	+0.080	0.190P-P	0.001	—	0.30P-P	0.010	+0.03	1.03P-P	0.008	—	+0.60	0.0110	—	1.00P-P	0.024
	B1P1	—	—	—	—	0.480P-P	0.015	—	0.12P-P	0.005	—	0.22P-P	0.010	—	0.40P-P	0.0080	—	0.20P-P	0.012
	C1B1	—	—	—	—	0.950P-P	0.006	−0.050	−0.34	0.004	+0.03	—	—	−0.05	+0.50	0.0024	—	—	—
	C1P1	[illegible]	0.320P-P	0.207	—	0.560P-P	0.015	−0.010	−0.52	0.010	−0.02	−1.20	0.062	—	0.40P-P	0.0220	−0.03	+0.30 −0.05	0.010
	B1B2	—	+1.300	0.010	−0.030	−1.100	0.027	−0.020	−2.40	0.022	—	−0.70	0.007	—	+0.40	0.0048	—	−0.50P-P	0.054
	B1P2	—	+0.510	0.049	−0.050	0.870P-P	0.085	—	−1.90	0.007	—	+0.70	0.004	—	0.20P-P	0.0360	—	0.25P-P	0.055
	C1B2	−0.1700	0.390P-P	0.033	−0.040	0.330P-P	0.007	−0.300	−0.30	0.028	—	+0.90 −0.20	0.004	−0.10	0.40P-P	0.0048	—	0.60P-P	0.061
	C1P2	−0.3000	−1.420	0.055	−0.040	+0.930	0.005	−0.080	+0.40 −1.10	0.033	—	−1.34	0.032	−0.08	+0.20 −0.60	0.0480	—	+0.50	[illegible]
	Control P	−0.0600	+0.753	0.004	—	0.080P-P	0.030	+0.010	0.16P-P	0.037	+0.01	+0.03 −0.05	0.018	—	0.20P-P	0.0370	—	+0.05 −1.30	0.005

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TABLE 28. VIBRATION TEST RESULTS
MIL-C-38999, MIL-STD-1344 Method 2005 II and
Fighter Aircraft Gunfire, MDC A3376, Section 4.2.8

Specimen	Test Circuit	Change in Losses (dB)
Non-Lanyard	BB-X	0
	BP-V	−1.5
	CB-AA	+0.5
	CP-Y	−0.4
Lanyard	BB-Y	+0.2
	BP-X	−0.2
	CB-V	0
	CP-AA	−0.8

Notes:
1. No discontinuities of 1 μsec or greater
2. No loosening of connector backshells

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TABLE 29. MECHANICAL SHOCK OPT DATA

1 Pre-Shock OPT With Jumpers(2) (dBu)	2 Post Shock OPT With Jumpers(2) (dBu)	3 Post Shock OPT With Jumpers(1) (dBu)	4 Post Shock OPT Without Jumpers(1) (dBu)
10.6	10.6	2.5	10.3
7.3	8.7	2.4	4.3(3)
12.9	12.4	7.3	9.4
13.1	12.6	7.6	8.1
16.1	16.0	8.5	9.5
14.3	13.7	7.7	11.2
10.9	9.7	3.7	9.0
14.3	13.7	7.7	11.9
15.4	15.3	10.1	13.4

Notes:
(1) Laboratory Controlled Source and UDT S550 Detector
(2) Continuous Sources and UDT S550 Detector
Continuous Sources were not disconnected between Test 3 and 4
Continuous Sources were not disconnected between Test 6 and 7
(3) SMA on B1P1 had Protruding Fiber (Pistoning)

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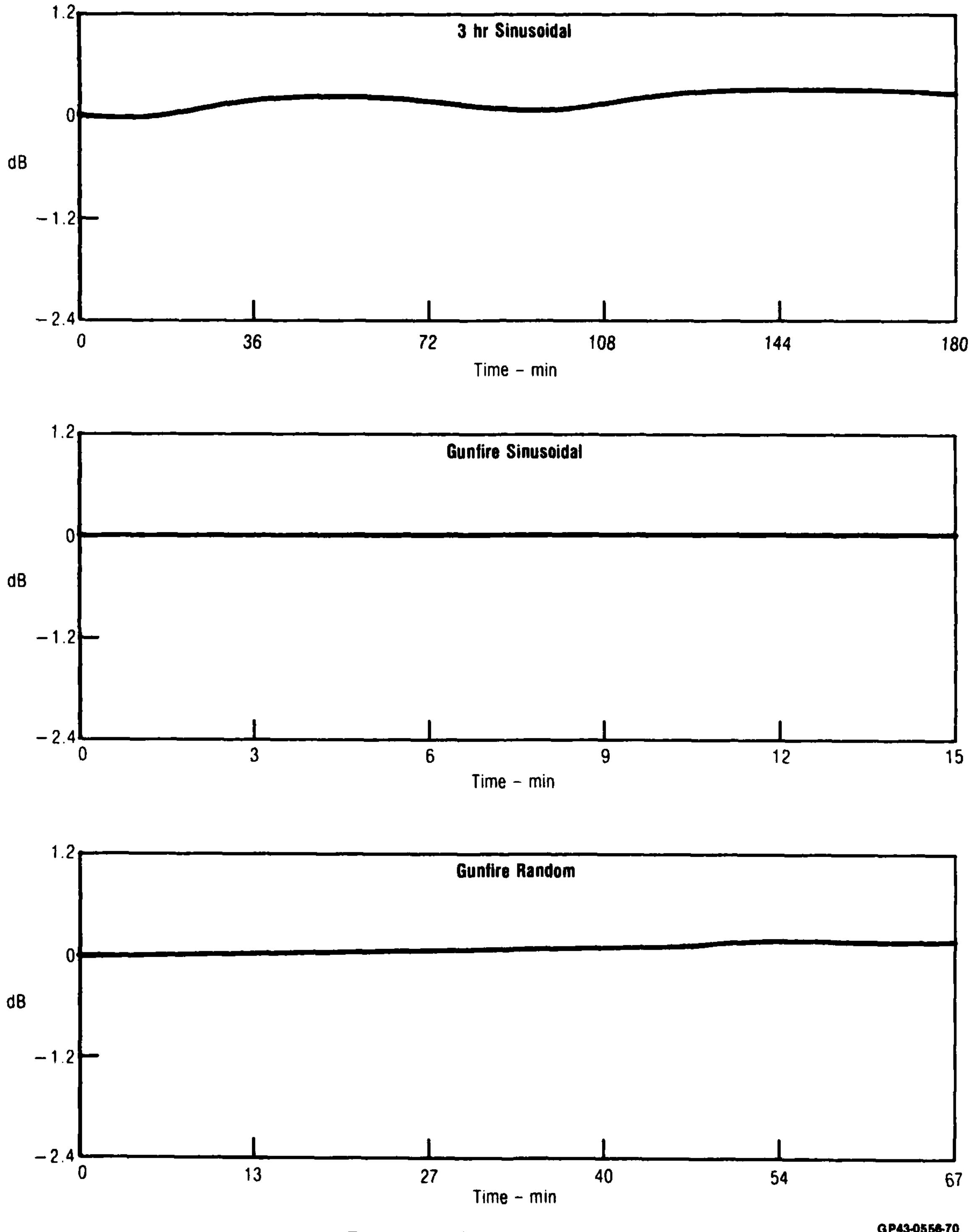

Figure 36. Vibration Test Data
Control P

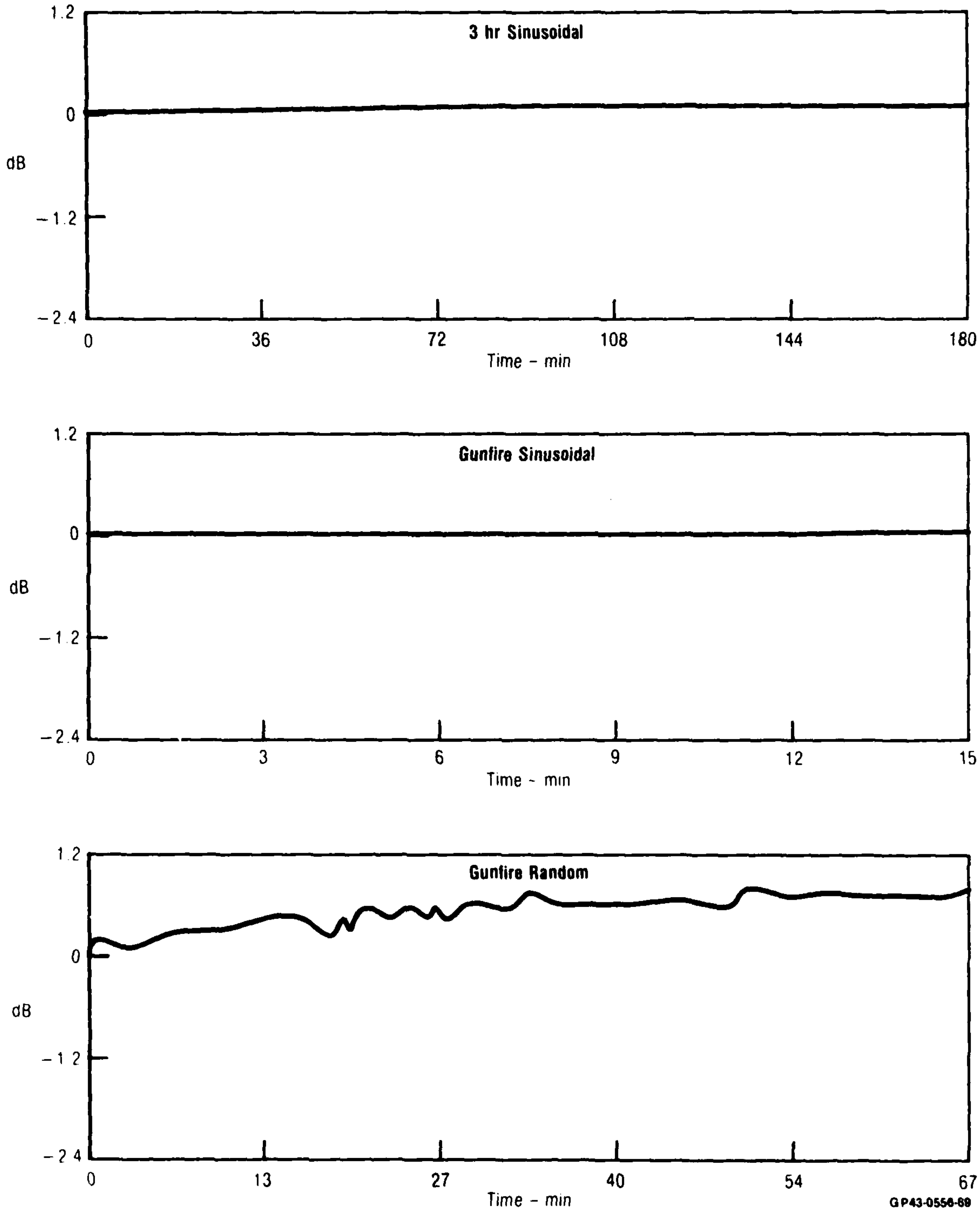

Figure 35. Vibration Test Data
C1P2-C2P2

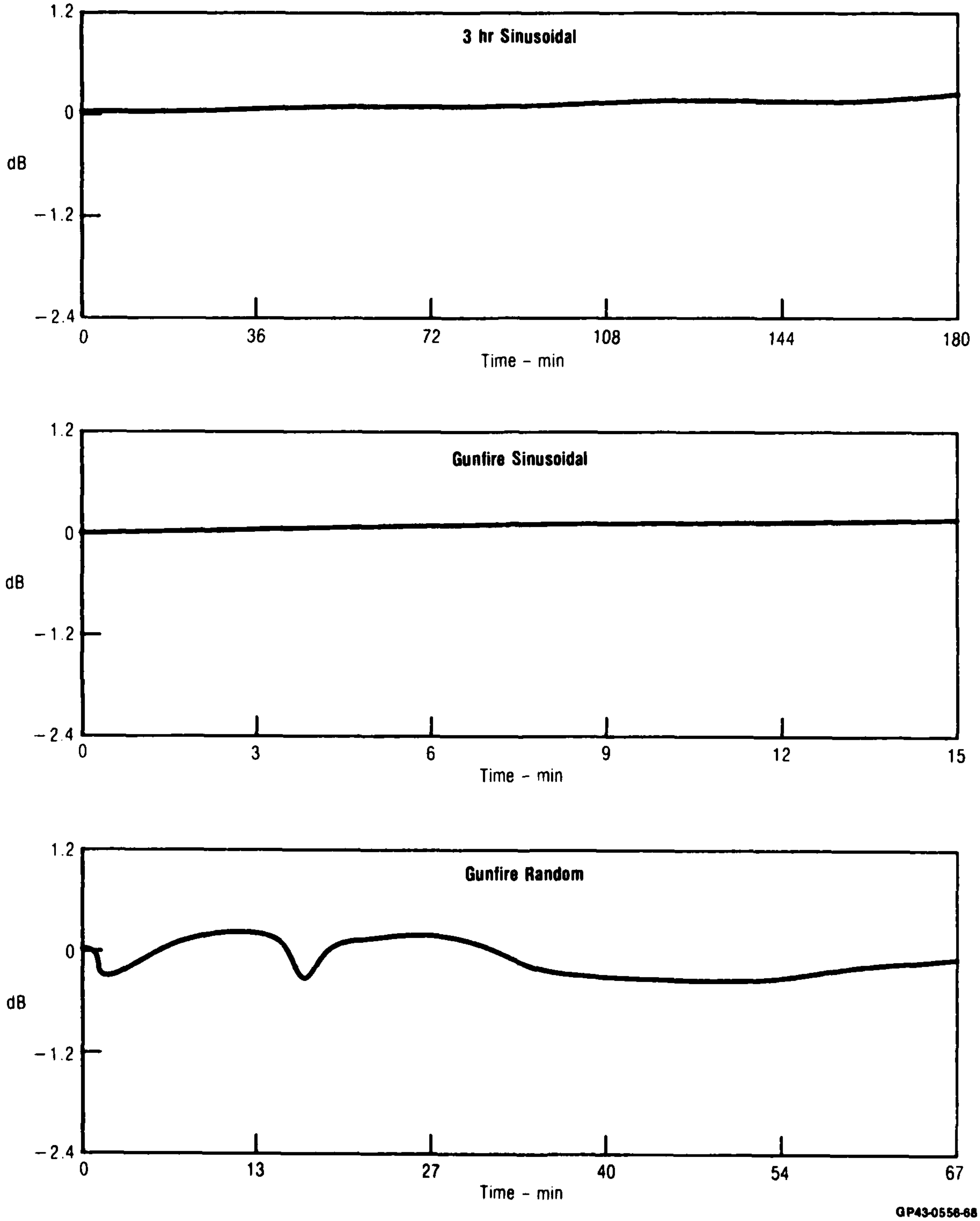

Figure 34. Vibration Test Data
C1B2-C2B2

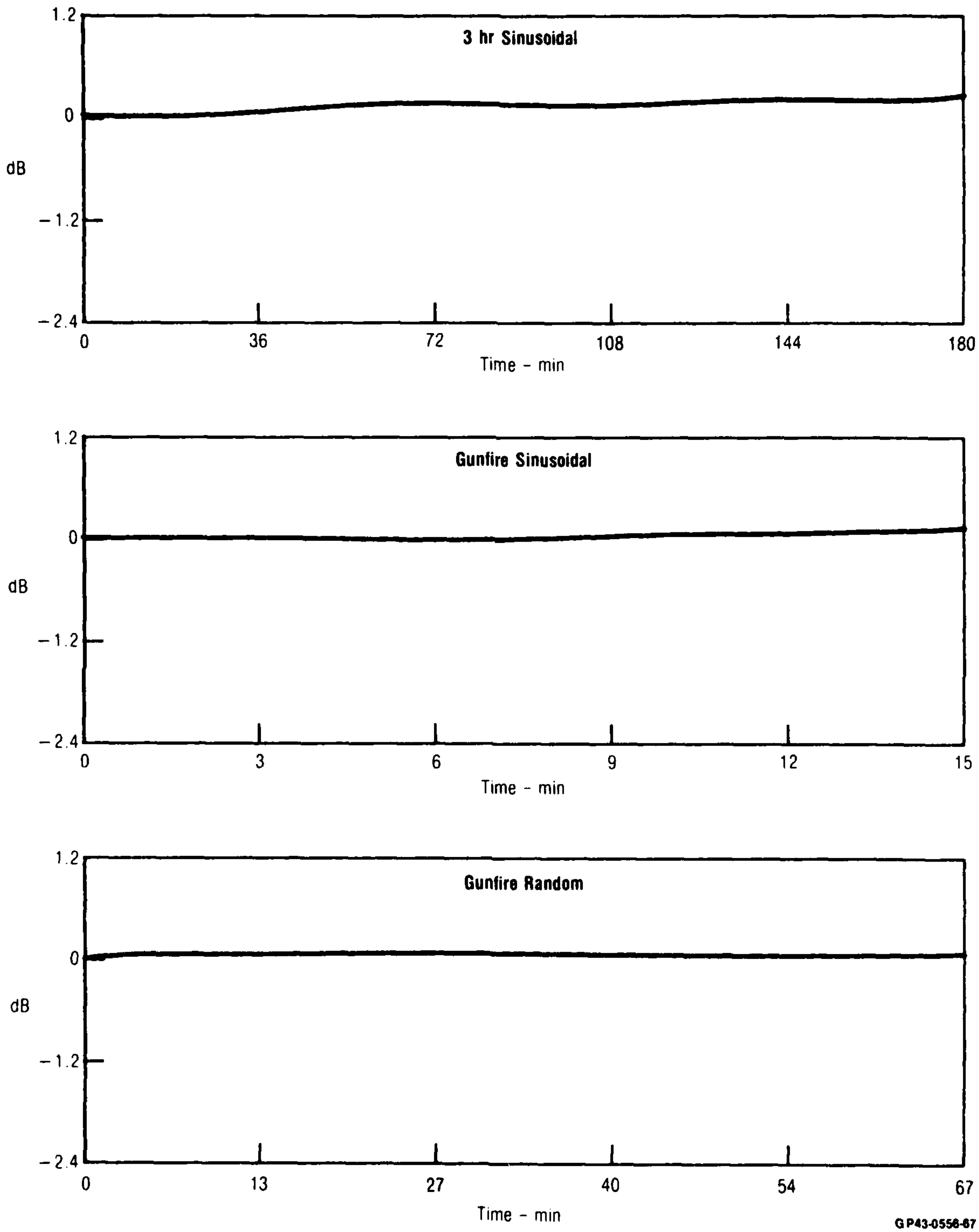

Figure 33. Vibration Test Data
B1P2-B2P2

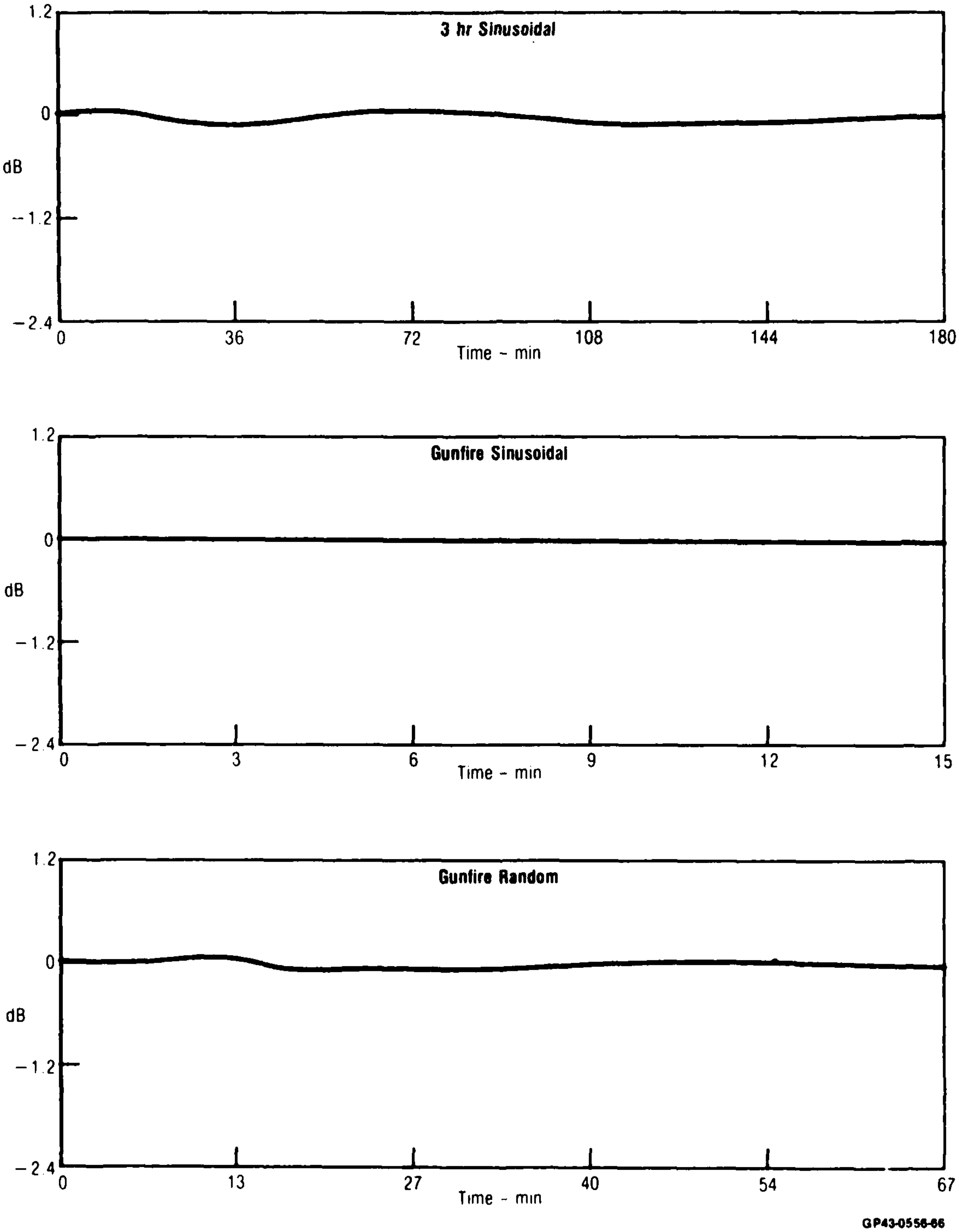

Figure 32. Vibration Test Data
B1B2-B2B2

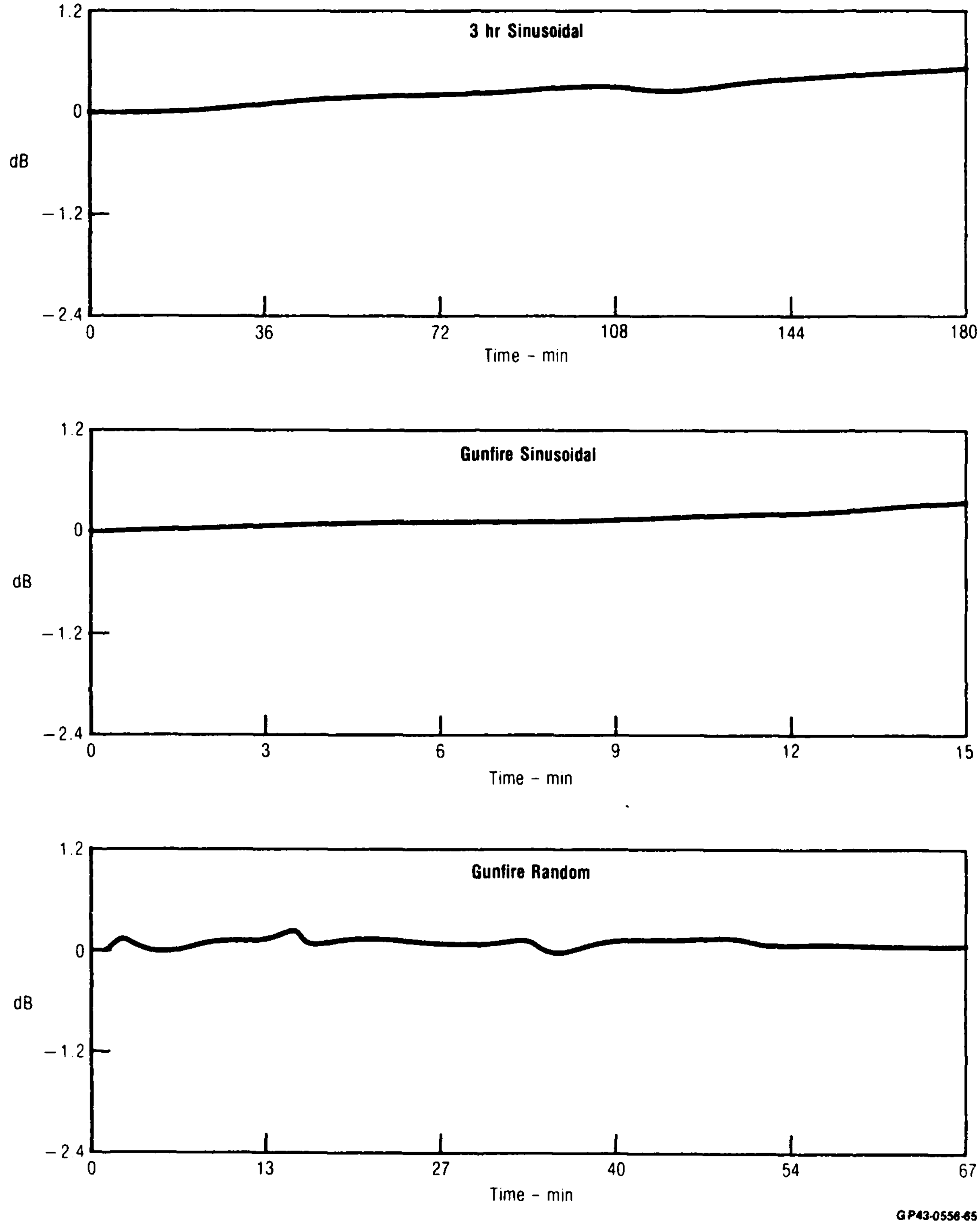

Figure 31. Vibration Test Data
C1P1-C2P1

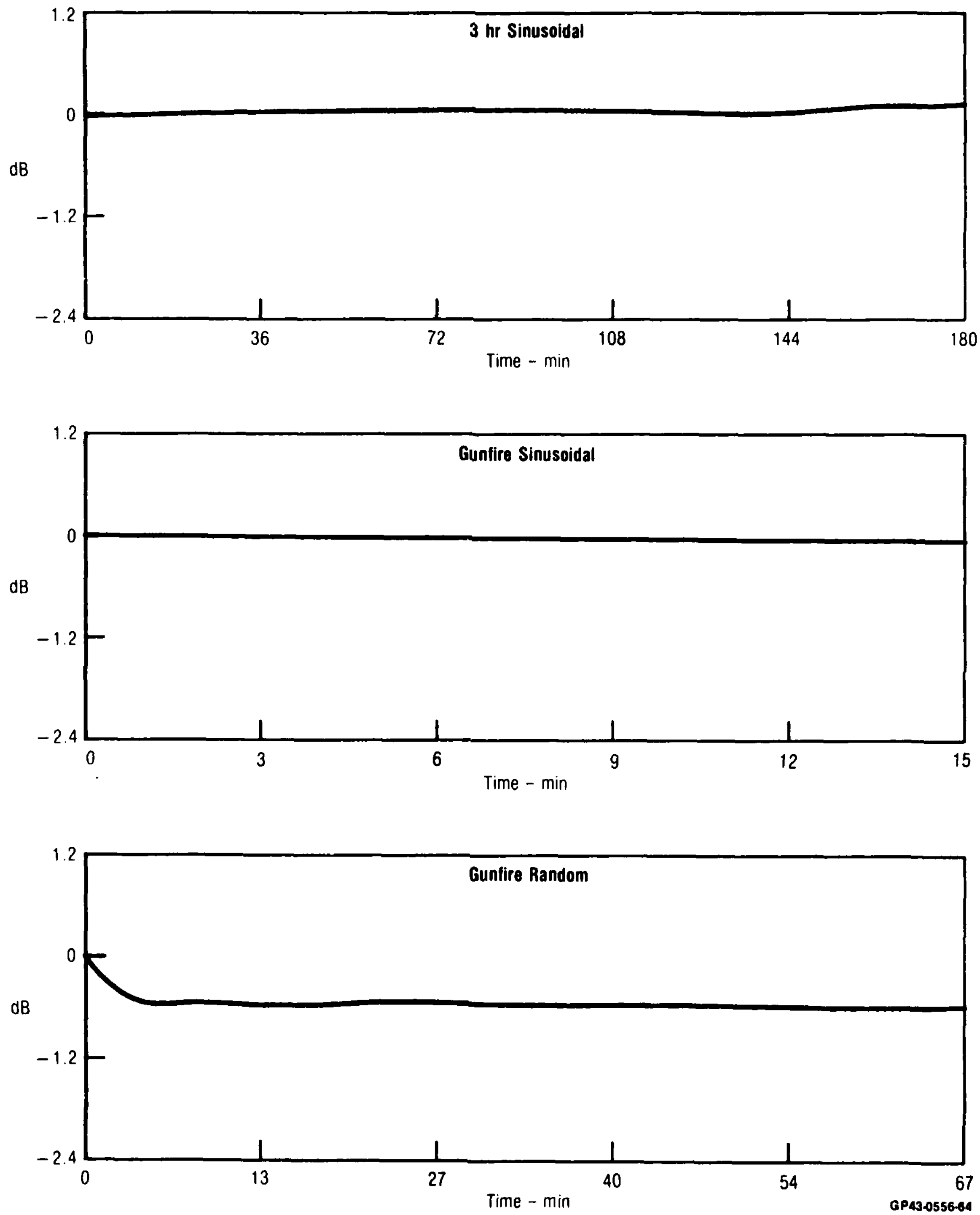

Figure 30. Vibration Test Data
C1B1-C2B1

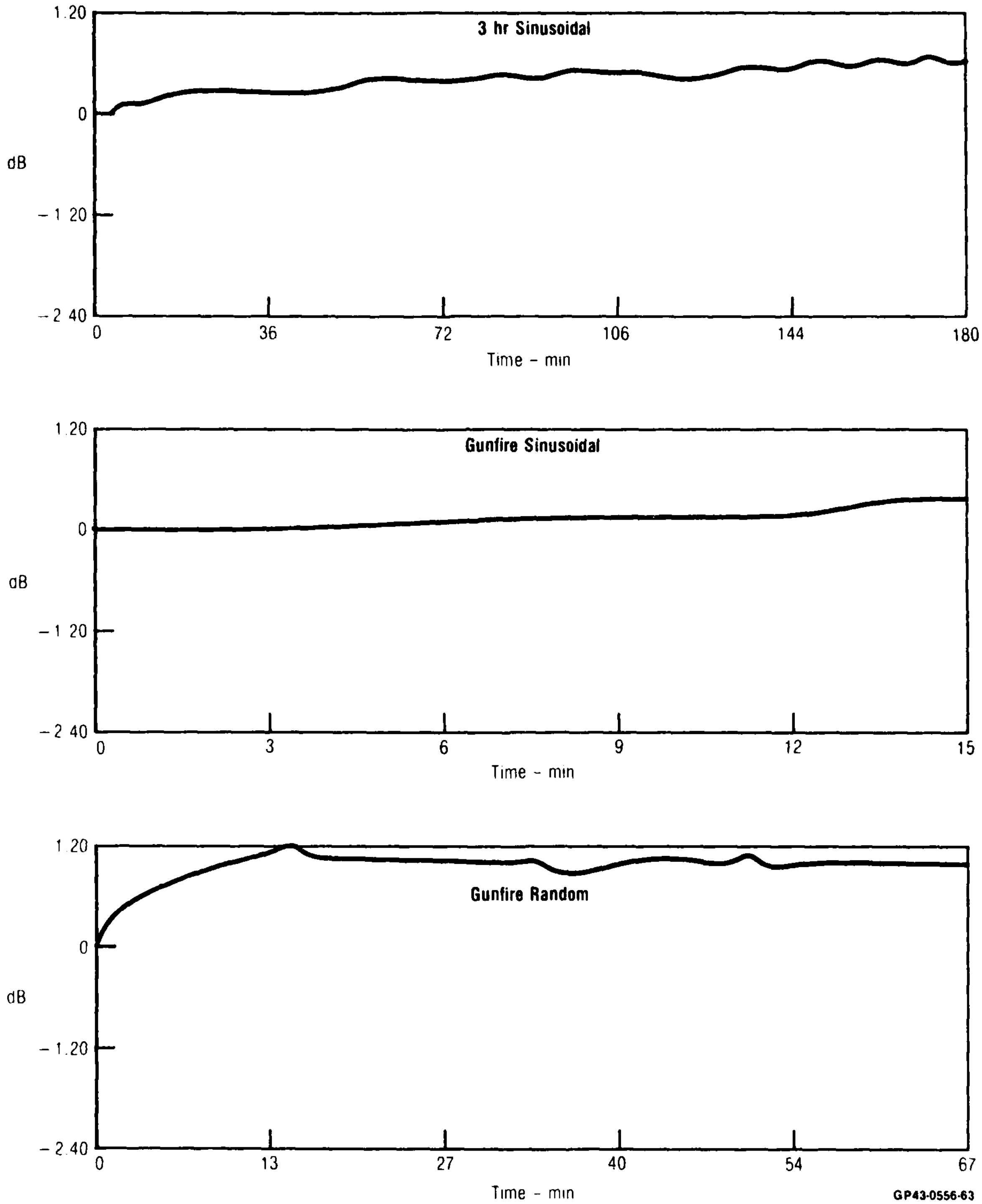

Figure 29. Vibration Test Data
B1P1-B2P1

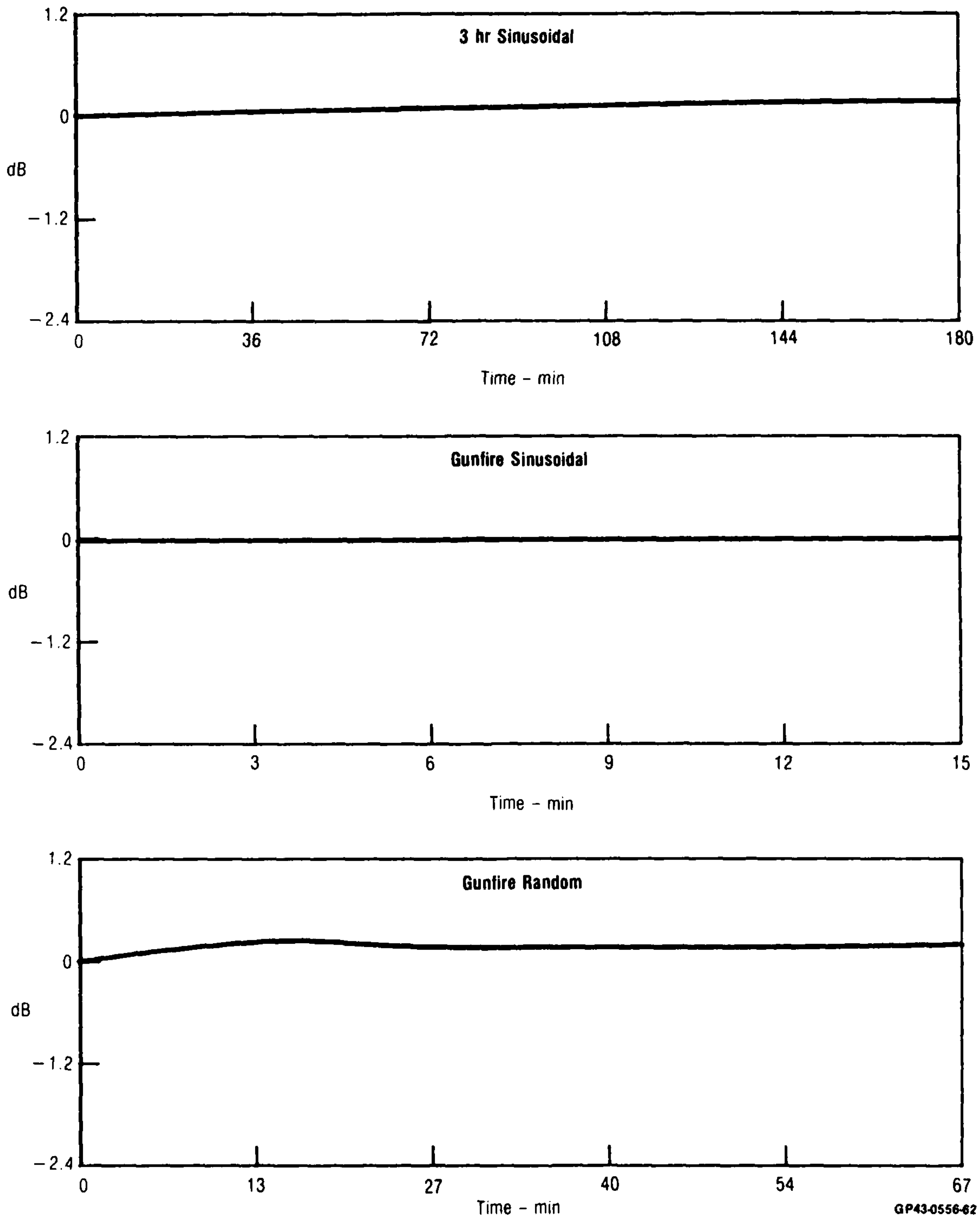

Figure 28. Vibration Test Data
B1B1-B2B1

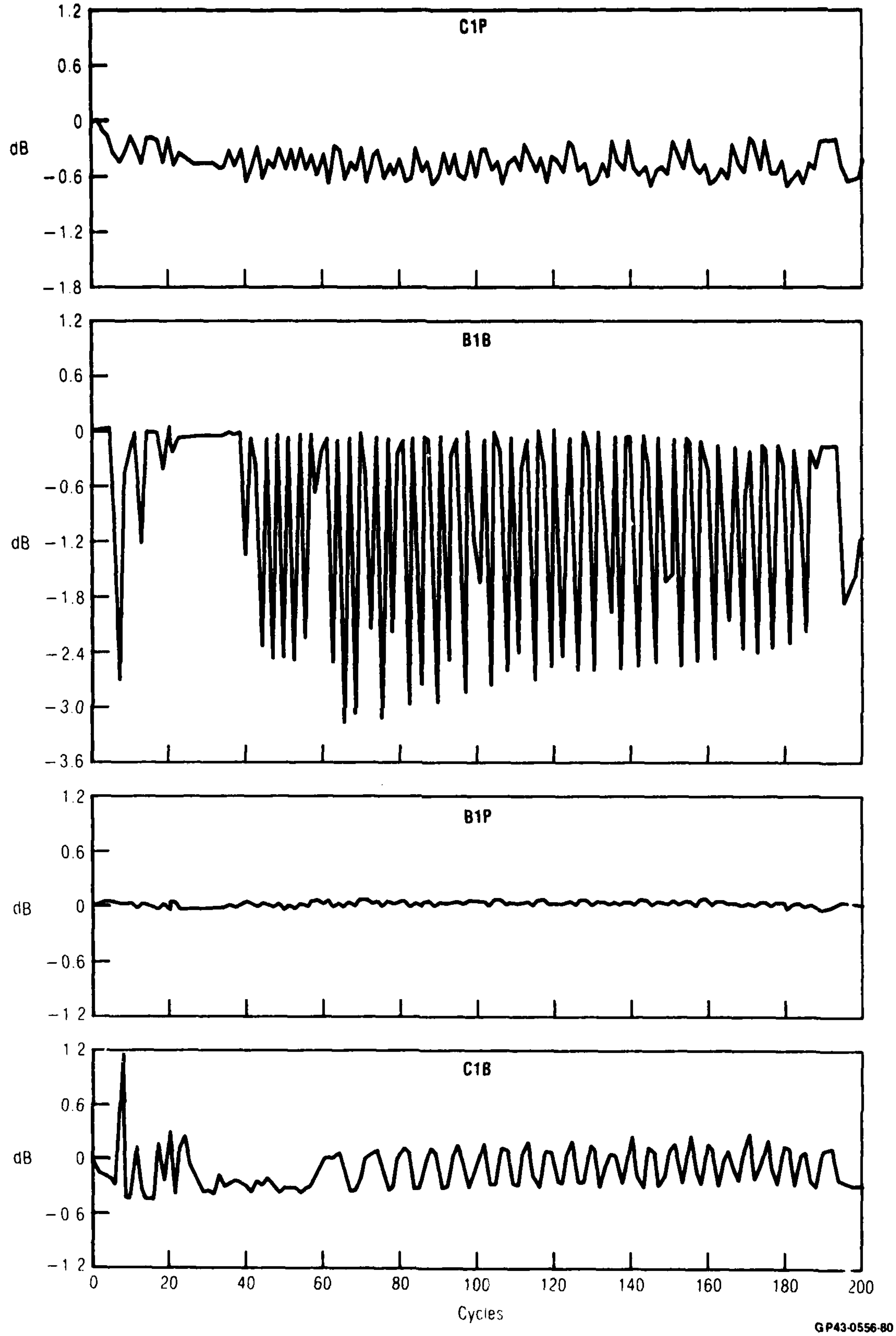

Figure 37. Flex Test
−40°C

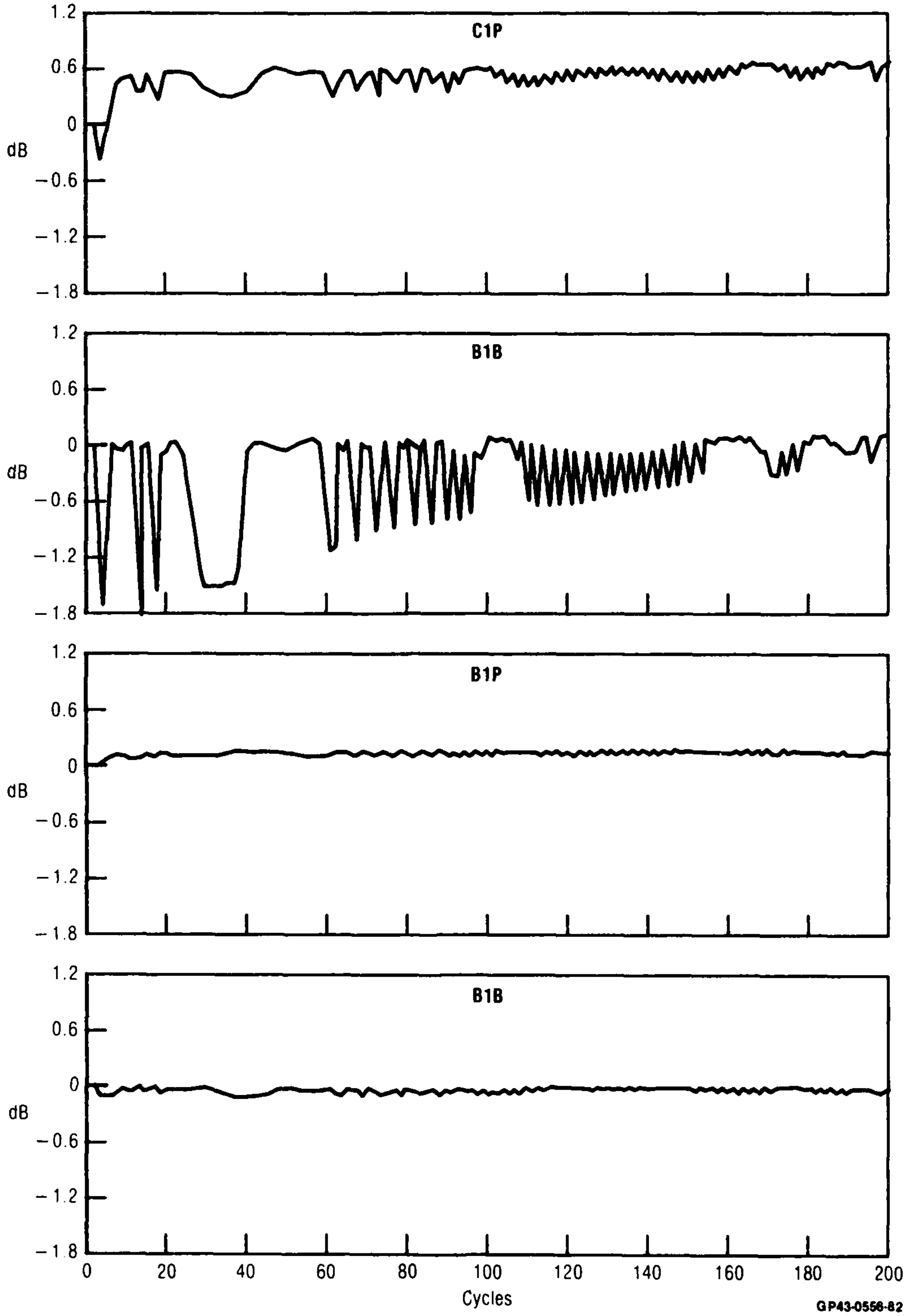

Figure 38. Flex Test
55°C

u. Harness Flex at Connector, 55°C - Sequence 21

See Sequence 20.

v. Tensile, Integrated Harness - Sequence 22 - Load and travel data are shown in Table 38. Tensile test data is shown in Table 39. Continuous measurement data curves are shown in Figures 39 and 40. A summary of the test data is shown in Table 40.

TABLE 38. LOAD AND TRAVEL DATA

Connector	Time (min)	Load (lb)	Travel (in.)
Straight (B)	0	100	0.263
	1.5	63	0.263
	2.0	62	0.263
	5.0	60	0.263
	5.0	100	0.284
	6.0	73	0.284
Right Angle (B)	0	100	0.269
	1.5	77	0.269
	2.0	76	0.269
	5.0	74	0.269
	5.0	100	0.286
	6.0	87	0.286

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TABLE 39. TENSILE TEST DATA

Identification	Initial Data		Post Data		Travel at 100 lb (in.)	Load Fall Back in 5 min (lb)	Travel at 2nd 100 lb (in.)	Load Fall Back in 5 min (lb)
	(dBu)(1)	(dBu)(2)	(dBu)(2)	(dBu)(1)				
B1B2 - B2B2*	9.8	15.1	15.1	10.7	0.283	59.5	0.284	73.0
B1P2 - B2P2*	9.5	17.8	17.2	10.2				
C1B2 - C2B2*	10.4	15.1	14.5	10.5				
C1P2 - C2P2*	8.7	16.5	16.4	9.2				
B1B2 - B2B4*	8.4	13.9	12.0	7.8	0.269	73.5	0.286	87.0
B1P2 - B2P4*	11.7	18.9	18.4	12.5				
C1B2 - C2B4*	9.3	13.4	13.6	8.9				
C1P2 - C2P4*	10.2	16.4	16.3	10.1				

Notes:
* Side of 38999 Connector under test
(1) UDT S550 Power Meter Reading with Laboratory Source
(2) UDT S550 Power Meter Reading with Conti uous Monitor Sources

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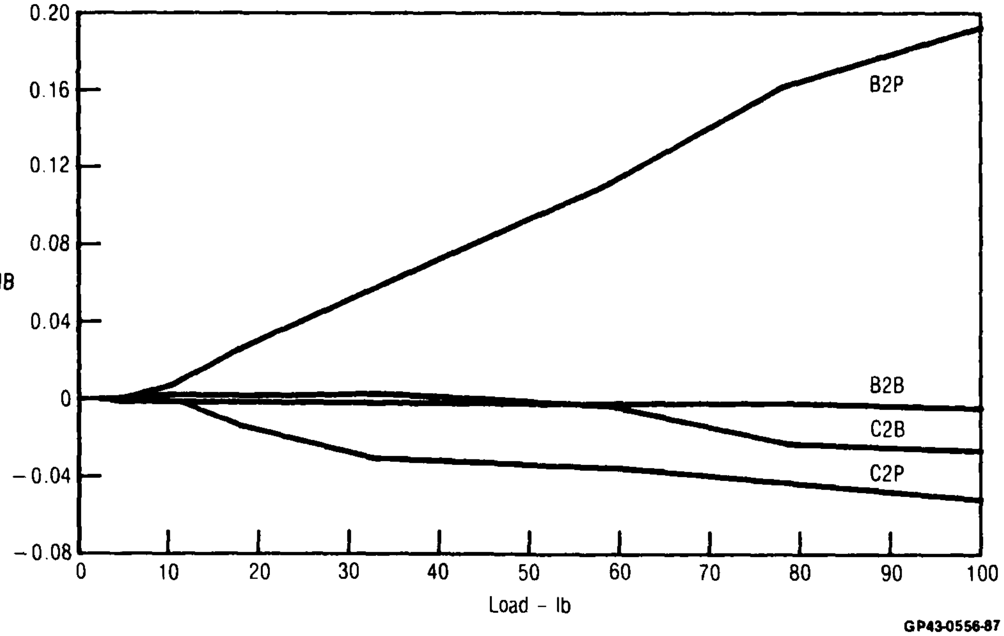

Figure 39. Tensile Test Data, Integrated Harness; Straight

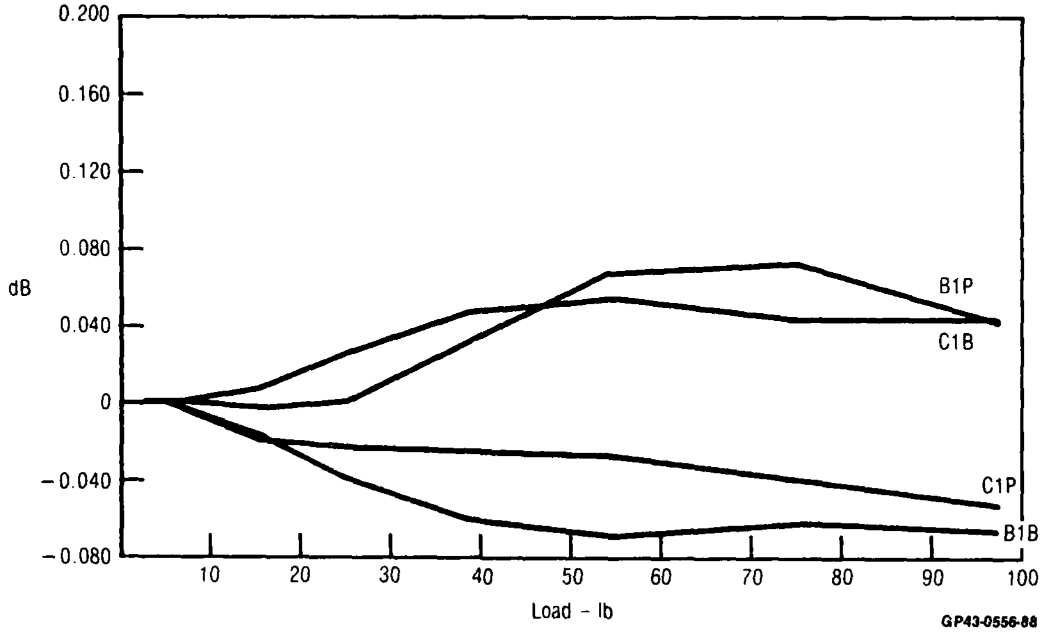

Figure 40. Tensile Test Data, Integrated Harness; Right Angle

TABLE 40. TENSILE TEST RESULTS

DOD-STD-1678 Method 3010 II Modified 100 Lb Load

Specimen	Test Circuit		Change in Losses (dB) 100 lb Pull
Lanyard	BB-Y	Pin	0
	BP-X	Pin	+ 0.6
	CB-V	Pin	+ 0.6
	CP-AA	Pin	+ 0.1
	BB-Y	Socket	+ 1.9
	BP-X	Socket	+ 0.5
	CB-V	Socket	− 0.2
	CP-AA	Socket	+ 0.1

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7. MAINTENANCE/REPAIR PROCEDURES

a. General - The maintenance and repair of fiber optics interconnect in the shop and in the field presents no unusual problems. These procedures have been documented in specification 1760-PS3 entitled "Maintenance/Repair Procedures, Aircraft Fiber Optics Interconnect." This specification is provided in Appendix H.

b. Fiber End Cleanliness - The MIL-W-5088 requirements for wiring of aerospace vehicles are also basic for fiber optics interconnect. However, the emphasis is focused on different areas than on the electrical interconnect. Cleanliness becomes critical with fiber optics, both in fabrication and in maintenance. Clean components are a necessity to achieve proper epoxy adhesion of the glass fiber to the terminating contact. The 100 micron glass core which transmits the information can be compromised by a single dust particle since the average dust particle is 50 microns in diameter. Therefore, protection of the polished fiber ends is necessary whenever they are not mated.

c. Slack Cable Storage - The requirement to provide extra cable for future retermination becomes more important with fiber optics interconnect, since excess slack may be stored by folding the cable back on itself. A clamp over this fold back could cause fiber breakage when a fiber optics cable is being stored.

d. Mating Tolerance - The axial mating tolerances of the electrical contacts are considerable when compared to the 0.001 inch gap tolerances of the fiber junctions employed in this system. Proper mating of connectors is stressed in fiber optics interconnect.

e. Splices - Unauthorized fiber optics cable splices are prohibited for the same reason that electrical cable splices are controlled; i.e., to ensure that losses do not exceed design limitations.

f. Damage Repair - The cable qualified in this program is very durable as demonstrated by the flex with cable indentation testing. Limited repair of cable damage has been provided by tape or sleeving buildup where the outer jacket and strength member have been damaged.

g. Troubleshooting - The diagnosis and correction of faults is different for fiber optics than for electrical circuitry. A trouble correction procedure has been provided in specification 1760-PS3.

h. Field Termination - The field termination of fiber optics cables is essentially the same as shop termination. Epoxy cure will probably be accomplished with a heat gun rather than an oven. Polishing introduces no unusual problems except for providing control of the water runoff used in the polishing procedure. Because of possible limitations in space and access, the termination time of a single contact could be expected to take longer than the 40 minutes elapsed time necessary for a bench termination. Most of the elapsed time is epoxy cure time; the manhour time is about 11 minutes.

i. Training - The differences between fiber optics and electrical interconnect are not great, but they are sufficient to require that personnel maintaining fiber optics interconnect be trained. This is a requirement of specification 1760-PS3.

j. Maintenance/Repair Specification - Specification 1760-PS3 contains the information necessary to maintain and repair the fiber optics interconnect during its field service life. This data is based on the fabrication and test experience derived from this program, as well as experience gained on the fiber optics interconnect system currently in operation on the production AV-8B aircraft.

8. SPECIFICATION DEVELOPMENT

Specifications have been developed to provide the data necessary to fabricate, install, and maintain the fiber optics interconnect. They are provided in Appendices B through M.

a. Component Specifications

1760-CS1 Fiber Optic Cable
1760-CS2 Fiber Optic Pin Contact, MIL-C-38999, Series III, #16
1760-CS3 Fiber Socket Contact, MIL-C-38999, Series III, #16

b. Process Specifications

1760-PS1 Interconnect, Fiber Optics, Fabrication of
1760-PS2 Interconnect, Fiber Optics, Installation, Aircraft
1760-PS3 Interconnect, Fiber Optics, Maintenance/Repair, Aircraft

c. Material Specification

1760-MS1 Epoxy, Two Part, Fiber Optics, Specification for

d. Training Specification

1760-TS1 Course, Training, Fiber Optics, Specification for

SECTION IV

DISCUSSION OF RESULTS

1. OPTICAL

a. Insertion Losses - Figure 41 shows the range of loss changes due to the insertion of the contact pair in the circuit and to the test environments. Insertion losses averaged 1.7 dB and 2.0 dB respectively for companies "NN" and "DD" termination systems when one unusually high and one unusually low value were deleted.

b. Test Environment Effects - Only in the company "DD" termination system Maintenance Aging/Durability tests did the losses from the test environments exceed the average insertion loss. The high company "DD" losses were due to a damaged spacer foil in the guide sleeve. The company "DD" termination system design has been altered to correct this problem. In general, the environmental and mechanical extremes affected optical losses no more than about 2 dB, or the equivalent of adding another pair of mating contacts to the circuit. This was true for the individual tests, and when the first and last serial test values were compared.

2. ENVIRONMENTAL

a. Thermal Aging - Of the environmental test extremes, only the 1000 hour 125°C thermal aging test produced significant changes. Both cables tested have a continuous temperature rating of 125°C. As seen in Figure 41, the optical losses were not unusually affected as measured continuously during thermal aging. However, in the Maintenance Aging test sequence, an unusual increase in losses was recorded on two of the circuits. Cable assembly movement during measurement caused a change in losses. When the cable assembly (harness) was stretched out straight, the losses in one circuit decreased by 3.8 dB when compared to the coiled measurement. The other three test circuits were measured while the cable assembly was stretched out. One circuit showed a dramatic decrease in losses; the other circuits were unchanged. The circuits with variable losses were both manufactured by company "X8". A similar situation with this lot of company "X8" cable had been experienced prior to this program. Company "X8" explained that the cabling had not been stabilized, allowing some surplus fiber length within the cable. They advised that the problem could be prevented by stretching the cable out straight and pulling the fiber after one end had been terminated. The procedure must be enacted prior to the second termination. The procedure was tried, the cables were successfully used in humidity cycling tests, and the procedure appeared to solve the problem. Lacking sufficient time to replace the company "X8" cable, it was used in this program. The test cables and jumpers were checked for heat problems, but none were experienced until after thermal aging. The problem apparently was triggered by the 1000 hour, 125°C thermal aging. We saw no changes on the continuous measurements during heat aging, but recorded some loss increases in before/after measurements on the two circuits with the company "X8" cable. A comparison of the stretched straight measurements with the measurements on the loosely coiled cable assemblies was made prior to the heat aging, and the results were much nearer to what was expected. Therefore, the values reported were based on the specimens being stretched straight.

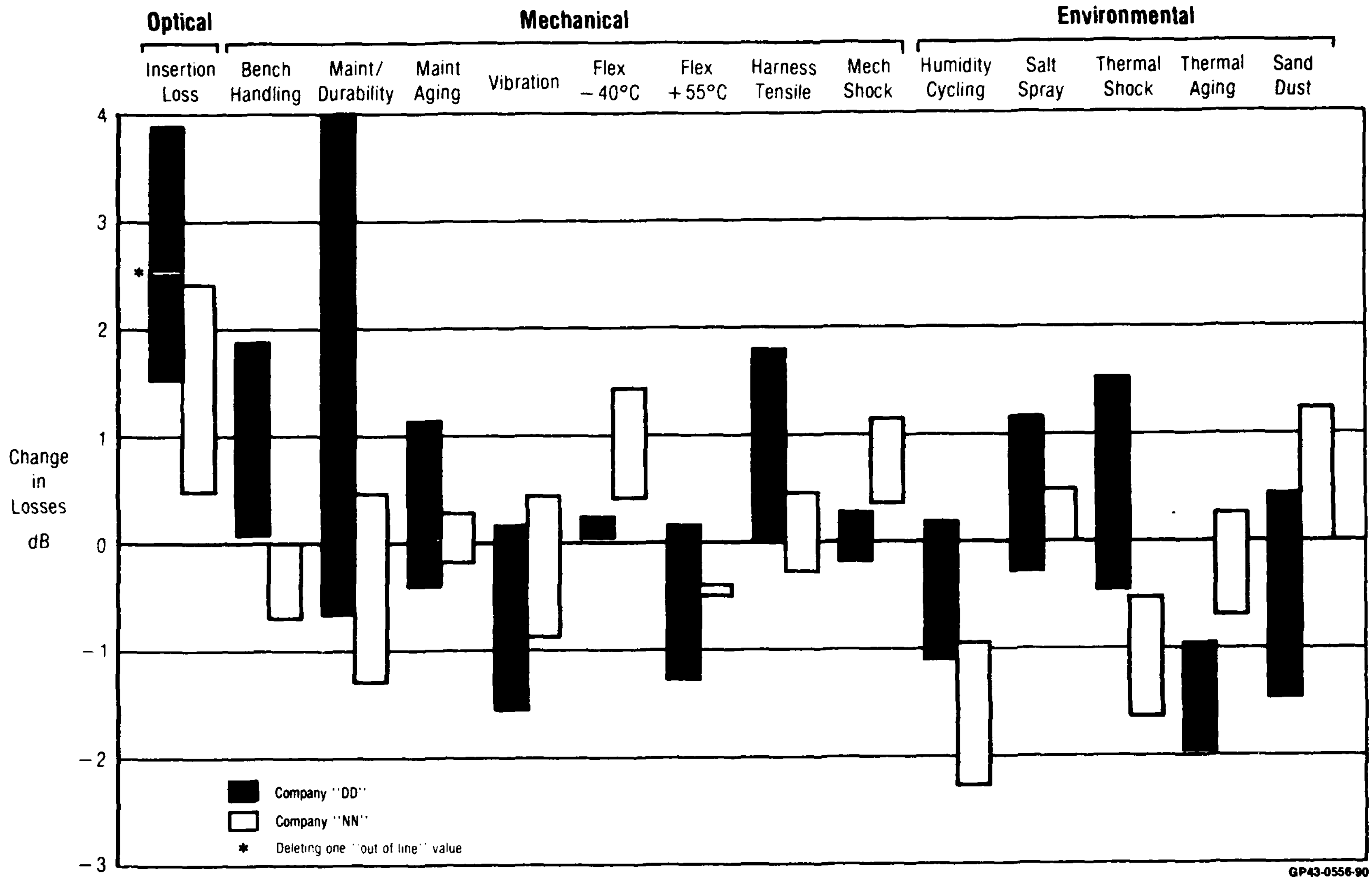

Figure 41. Range of Test Measurements

b. Maintenance Aging - Following the Maintenance Aging procedure, one of the contacts exhibited high losses. During handling to determine the cause of the high losses, the contact broke off at the point where the cable enters the contact. Failure analysis of the contact and cable could not determine if the breakage had been due to heat or due to the handling. The broken cable was a company "X8" cable. The inner jacket of Hytrel had darkened compared to the nonthermally aged material. The inner jacket material used by each cable company was tested. Table 41 shows that some of the physical characteristics of Hytrel had changed as a result of heat aging at 125°C. The published continuous thermal rating for Hytrel 4276 is 103°C, which is the maximum rating for the cable. No specific failure could be attributed to the inner jacket.

TABLE 41. INNER JACKET MATERIAL

Test Procedure	Cable A New	Cable A After Thermal Aging	Cable A Percent Change	Cable B New	Cable B After Thermal Aging	Cable B Percent Change
Deflection	17.00	19.50	16	6.90	7.10	+3
Hardness	87.00	91.00	+4	87.00	91.00	+4
Strength	0.50	0.48	−4	0.45	0.50	+10

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c. Shrinkage - Thermal Aging also caused shrinkage of up to 1/4 inch of the outer Tefzel jacket. Cable from both manufacturers were subject to the shrinkage. The outer jacket was terminated flush with the rear of the contact. When shrinkage occurred, the flexural forces were concentrated on the inner jacket.

d. Salt Spray/Sand and Dust - In both the salt spray and the sand and dust tests, connectors were unmated during the full environmental exposure. After salt spray, the fibers were rinsed with water and the losses measured. The contacts were then solvent cleaned, and the losses remeasured. There was no significant change in the losses. When the unmated sand and dust connectors were cleaned with pressurized clean dry air, losses had increased, but recovered to normal values after solvent cleaning.

3. MECHANICAL

a. Limitations - The mechanical limitations revealed in this test program have been mentioned in the preceding discussion. They are the damage and loss of the spacer in the guide sleeve of the company "DD" contact, and the inability to captivate the cable jacket within either of the contacts. The company "DD" connector design employs a thin spacer in the guide sleeve to prevent the fiber in the spring loaded socket contact from wearing against the pin contact fiber. There were problems with the spacer loosening as early as the fiftieth cycle of the 500 durability cycles.

(1) Manufacturer Response - In response to the program results, company "DD" has redesigned the contact assembly and is currently performing tests to verify the improvement.

b. Strain Relief - The backshell strain relief hardware used on each of the test connectors provided the necessary strain relief. However, one cable broke at the contact/cable junction during handling, when it was not supported by the strain relief hardware.

c. Vibration and Mechanical Shock - All components successfully withstood the rigorous vibration and mechanical shock tests. Vibration testing included a gunfire exposure, and mechanical shock testing included 300g drops. There were no discontinuities of one microsecond or longer. There was no loosening of the mated connectors or of the backshells.

4. EPOXY BONDS

a. Test Specimen Disbonds - There were two fiber disbonds on company "NN" contacts. They were traced to air entrapment and to insufficient fiber/epoxy adhesion. Both disbonds were discovered after the salt spray test sequence. Since the connectors were not disconnected after the humidity cycling test which preceded the salt spray, it is likely that the disbond occurred during humidity cycling.

b. Control Specimen Disbond - During the test, a control cable with SMA contact terminations also experienced a disbond. Failure analysis indicated a lack of fiber/epoxy adhesion.

c. Epoxy Application Details - Lack of attention to epoxy application details can result in epoxy disbonding. When this occurs, the fiber end location is no longer fixed within the contact. The disbond may occur when the connection is exposed to temperature extremes or changes and may not be discovered until the connection is unmated and then remated. The loose fiber may then break off or wear at the fiber ends.

5. CABLE

a. Cable Qualification - Because of the thermal stabilization problems discussed in Paragraph IV.2, the company "X8" cable did not completely qualify. The company "X3" cable met all the program requirements and is qualified for a MIL-STD-1760 interconnect system.

6. TERMINATION SYSTEM

a. "NN" Contact - The company "NN" contact termination system met all the program requirements. The average insertion loss was 1.7 dB. The highest recorded insertion loss was 2.4 dB. The highest loss increase due to the test extremes was 1.5 dB. Loss values were consistent throughout the 500 durability cycles and 10 maintenance aging cycles. The company "NN" termination utilizes a ruby jewel to center the fiber at the polishing surface. Since the ruby is harder than the glass, polishing results in the glass fiber being slightly concave. This provides inherent fiber separation in the fiber to fiber coupling and added protection to the polished fiber end from mechanical damage. This system also permits customizing the jewel to the size of the fiber being used. In this program, the jewels were factory installed, and sized to accommodate the expected fiber diameter tolerances. The system allows optimization of fiber to fiber alignment.

b. "DD" Contact - The company "DD" contact termination system met all the program requirements, except that Maintenance Aging/Durability losses were excessive. This was caused by the displacement/loss of a spacer foil which is located within the socket contact guide sleeve. The manufacturer has made design changes and is performing tests to verify the improvement. The average insertion loss was 2.2 dB. There was one high value of 3.9 dB which may have been caused by the spacer problem. Discarding this value, the average of the other 10 insertion loss measurements was 2.0 dB, and the highest value was 2.5 dB. The highest loss increase due to the test extremes other than maintenance aging was 1.8 dB. The company "DD" contact extended approximately 3/32 inch beyond the rubber connector insert. Although unusual, it caused no problems. The connector strain relief backshells provided the necessary flexural strength when the interconnect was fully assembled.

7. SPECIMEN CONFIGURATION

a. Insert Arrangements - Figure 4 shows the interconnect test specimen configuration. Within each of the mated pairs of connectors shown, there were four fiber optics circuits. The MIL-STD-1760 connector is the Series III version of MIL-C-38999 with a 25-20 insert arrangement (Figure 3). However, this connector was not available. A 25-46 insert arrangement was used for this test program (Figure 3). The 25-46 arrangement provided four size 16 cavities located near the central insert portion similar to the 25-20. It also contained two size 8 cavities similar to those found in the 25-20 arrangement. The military version of this connector had not been qualified at the time for ordering hardware, so an identical commercial version was used in the test program.

b. Cable/Contact Configurations - Two of the four fiber optics circuits were used for company "NN" contacts, and two for company "DD" contacts. One of each pair of contacts was fabricated with company "X8" cable, and one with company "X3" cable.

c. Statistics - The small number of specimens in the program did not cause any problems and the results were consistent.

8. ASSEMBLY

a. General - Assembly procedures are furnished in 1760-PS1. They are similar to other epoxy/polish procedures: strip cable, clean parts, mix epoxy, apply epoxy, cure epoxy, polish fiber end, and assemble parts.

b. Manufacturer Procedures - Procedures from companies "NN" and "DD" were utilized to tailor the termination to the cable chosen for the program. The company "DD" procedure was significantly changed by deleting the use of a ferrule inserted into the rear of the termination for easing strain relief insertion. By analysis and experimentation, it was determined that the change would improve flexural strength and reduce assembly time. Company "DD" agreed with the change.

c. Strength Member Insertion - Guiding the limp braided strength members into the contact cavity is the most difficult step. A wrap of non-adhesive tape holds the braid in place until insertion; then the tape is removed.

d. Assembly Time - Assembly time for a single termination is about 40 minutes. This is based on 5 minutes to strip the cable and assemble the contacts, 30 minutes to cure the epoxy, and 5 minutes for polishing. The elapsed time needed to replace a termination on an aircraft in service may be longer. Assembly and cure times can be shortened by mechanization, but the epoxy cure time offers the best source for shortening the termination time.

9. MAINTENANCE

a. General - A single particle of dust on the polished fiber can reduce optical power. In this test program the socket contacts, in particular, had to be watched for collecting the bits of rubber chipped off the insert during repeated insertion/extraction of the contacts. Storage of slack cable is critical. A cable clamp over a 180° foldback in a fiber optics cable may cause the cable to break. The minimum bend radii restrictions of both fiber optics and electrical cables prohibit cable foldback conditions. Minimum bend radii rules must not be ignored when slack cable is being stored.

b. Troubleshooting - The problem diagnosis of fiber optics interconnect is different than for electrical circuitry. 1760-PS3 contains troubleshooting methods and maintenance and repair procedures.

10. IDENTIFICATION

a. General - No identification problems were encountered on this program, but the interconnect system was not mixed with all electrical interconnect systems. In a MIL-STD-1760 application, interconnect mixing will occur. There is a significant difference in contamination tolerance between fiber optics and electrical interconnect. The personnel who service the aircraft that contain both systems must be aware that the fiber optics system is part of the interconnect.

SECTION V

CONCLUSIONS

1. General - The objectives of the program were met.

2. Qualified System - A fully tested fiber optics interconnect system consisting of a company "X3" cable terminated into a company "NN" contact is suitable for MIL-STD-1760 flight applications.

3. Insertion Losses - The insertion losses of this system are 1.8 $\pm$ 0.6dB. Additional losses caused by the environmental and mechanical testing generally did not exceed the average initial insertion loss. The additional losses were not cumulative. Within the test measurements (initial and final measurements using threaded test connectors which had been disconnected), there was no indication of permanent increase of losses. System losses were consistent.

4. Backup System - A backup system was partially qualified with comparable loss characteristics. In this system, company "X3" cable is terminated into company "DD" contacts. The termination system was not fully qualified due to problems with the spacers during Durability and Maintenance Aging testing. The manufacturer has made design changes to correct this deficiency and is currently performing tests. Contingent upon successful retesting, the back-up system is a potential alternate qualified system. This system is interchangeable with the qualified system, but they are not intermateable. Table 42 shows a summary of the system losses.

TABLE 42. SUMMARY OF SYSTEM LOSSES

		Fully Qualified System, 125°C Rating	Partially(1) Qualified System, 125°C Rating(2)
Termination, Company "NN"		X	
Company "DD"			X
Cable, Company "X8"			
Company "X3"		X	X
Insertion Loss	dB	1.8 ± 0.6	2.0 ± 0.5
Max Loss From Any Test Sequence	dB	1.8	2.0
Max Loss, Cumulative for Test Series	dB(3)	2.0(4)	1.3

Notes:
(1) Spacer loss problem in Durability/Maintenange Aging. Manufacturer has redesigned.
(2) System temperature limitation due to cable.
(3) These values subject to reconnection of threaded connectors. Variation of up to 1 dB.
(4) SMA test connector had a protruding fiber.

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5. Fabrication and Installation - The fiber optics interconnect system can be fabricated on a production basis, installed in a military aircraft without any unusual problems. This conclusion is based on the production experiences with the single channel fiber optics system on the AV-8B production aircraft and supported by the fabrication and test experience of this program.

6. Maintenance - The maintenance of the MIL-STD-1760 fiber optics interconnect system in field service is not expected to restrict its application. As demonstrated by the program testing, the interconnect is durable. The most important factor in the maintenance of the interconnect system is cleanliness. In the field, the main obstacle to successful operation will be contamination and debris which could interfere with the fiber to fiber transmission of the optical signal. This system can be maintained in the field by regular service personnel after a short training program (1760-TS1).

7. Epoxy - The most important factor in the fabrication of the interconnect system is the application of the epoxy. Maximum support of the fiber by the epoxy can be achieved by the use of clean parts, by the absence of air bubbles in the epoxy, and by the use of proper strip lengths. These application procedures are detailed in 1760-PS1.

8. Military Aircraft Environment - Hybrid fiber optics and electrical interconnect are feasible for rigorous military aircraft environments. The optical performance of the interconnect system was not severely affected by the environmental and mechanical extremes of this test program.

9. Jacket Shrinkage - The cables tested were subject to excessive outer jacket shrinkage (up to 1/4 inch at terminations) from thermal aging. The specification for the cable, 1760-CS1, includes a jacket dimensional stability test which limits jacket shrinkage to 1/16 inch maximum.

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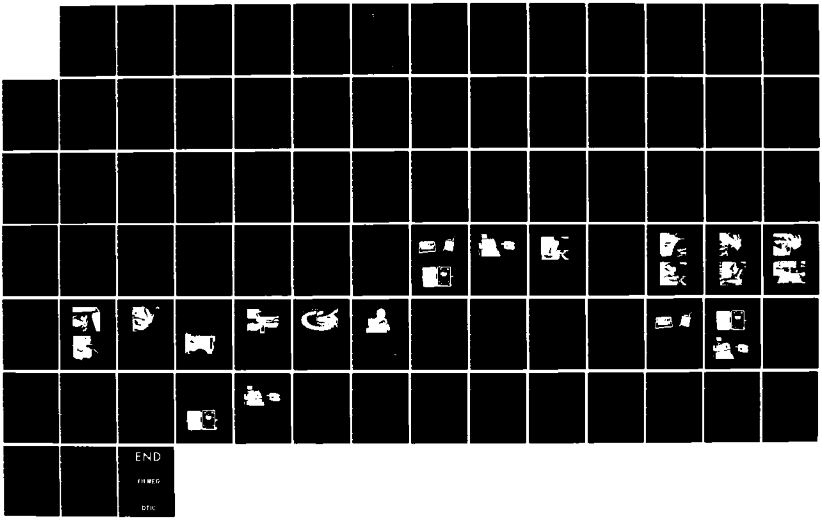
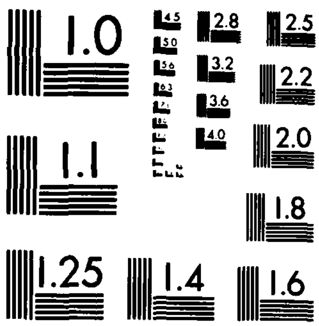
UNCLASSIFIED F/G 1/3 NL




1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

SECTION VI

RECOMMENDATIONS

1. Smaller Diameter Cable - The cable jacket was too large to be terminated within the contact. The contact diameter cannot be increased to accommodate the cable since this dimension is fixed for tooling, etc. Qualification of a smaller diameter cable, about 0.083 inch in diameter, is recommended. This would significantly improve the flexural and tensile strength of the cable/contact junction.

2. Higher Temperature Cable and Epoxy - Qualification of a higher temperature (up to 200°C) system is recommended. This would require a higher temperature cable and epoxy.

3. Short Cure and Lower Cure Temperature Epoxy - Field replacement of contacts is practical but the 30 minute cure time required by the epoxy should be reduced. Field repairs would also be simpler with a lower temperature cure epoxy. Qualification of short cure time and lower cure temperature adhesives is recommended.

4. Factory Installed Jewels - The fully qualified termination system employs a jewel to center the fiber at the polishing surface. The jewel may be field installed to produce minimum alignment losses or factory installed to simplify the procedure. The use of the factory installed jewel is recommended.

5. Identification - Connectors containing fiber optics terminations should be easily identified so that they can be protected from contamination when they are unmated. Efforts to address this problem have been initiated both through the MIL-W-5088 Standard for Aerospace Vehicles and through the P6 Fiber Optics Committee of the Electrical Industry Association (EIA). It is recommended that fiber optics standard identification procedures continue to be pursued, and be implemented as they are developed.

6. Permanent Splice - Test and production experience with the cable proved it to be durable and resistant to installation and maintenance type handling. However, mechanical damage can be expected to occur which would require replacement or splicing of the cable. Past experience has also shown that design modifications may require splices to cables. Qualification of a permanent fiber optics splice based on the contact hardware qualified by this program is recommended.

APPENDIX A

EQUIPMENT LIST

TABLE A-1. TEST EQUIPMENT

Laboratory-Built Feedback-Controlled LED Light Source
UDT Model S550 Optical Power Meter
Controlled LED Source, Spectronics LED #SE3352-004
Light Level Detector With Light Loss Detector-Latch Circuit, Hamamatsu Detector #21188.
Data Logger (Fluke Model 240B)
Tape Recorder (Tektronix #4923)
Computer (Tektronix #4051)
Hard Copier (Tektronix #46731)
Oscillograph (Honeywell, Model 1858

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APPENDIX B

1760-CS1 - CABLE, FIBER OPTIC

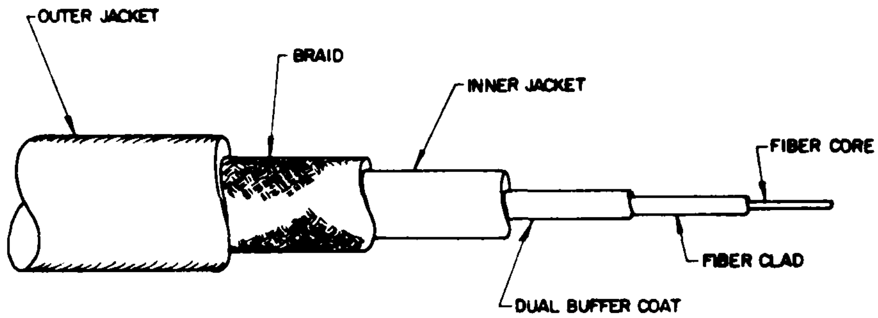

FIGURE B-1 -5M1945-001 OPTICAL FIBER

APPROVED CALLOUT
5M1945-001

TABLE I
CONSTRUCTION DETAILS

APPROVED CALLOUT	5M1945-001
OPTICAL FIBER	SEMI-GRADED, SINGLE FIBER CORE DIA. - .0039 + 00004 INCHES CLAD MATERIAL - SILICA GLASS CLAD DIA. - .0055 + .0001 INCHES
BUFFER COAT	UV CURABLE, THERMOPLASTIC RESIN COAT DIA - .019 + .003 INCHES
INNER JACKET	HYTREL, TYPE 7246 INNER DIA - .025 INCHES MIN OUTER DIA. - .059 INCHES MAX
BRAID	TEFLON IMPREGNATED FIBERGLASS 150-1/2-2 ENDS 10 PICKS PER INCH
OUTER JACKET	TEFZEL 200 COLOR - VIOLET DIA. - .110 + 003 INCHES
CONCENTRICITY	.80 MINIMUM FOR CORE, CLAD, INNER AND OUTER JACKET .70 MINIMUM FOR BUFFER COAT
TOTAL WEIGHT	6.8 LBS/1000 FEET
MINIMUM CABLE LENGTH	500 FT

TABLE II

	OPTICAL AND MECHANICAL PROPERTIES	
	APPROVED CALLOUT	5M1945-001
	MAX. ATTEN @ 900 nm	1.5-3.0 db per 1000 ft
	NUMERICAL APERTURE	Steady State $\geq$ .30
B	CORE/CLADDING REFRACTIVE INDEX	1.48/1.4528
B	BANDWIDTH	100m Hz - 3300 ft
	FIBER TENSILE PROOF TEST	100,000 psi min
	BRAID BREAK FORCE	80 lbs
	JACKET TENSILE STRENGTH & ELONGATION	5,000 psi min., 200% min

DIMENSIONS IN INCHES: TOLERANCES UNLESS OTHERWISE SPECIFIED: .XX ± 0.03; .XXX ± 0.010; ANGLES ± ½°

FSCM NO. 76301	TITLE CABLE, FIBER OPTIC	CLASSIFICATION STANDARD PART DOCUMENT
PROCUREMENT SPECIFICATION DOD-C-85045		5M1945 SHEET 1 OF 3

APPROVAL DATE: MAY 1980 REVISION:

GP43-0888-4

NOTES: 1. GENERAL: THE SPECIFICATION DESCRIBES THE REQUIREMENTS FOR A FIBER OPTIC CABLE MANUFACTURED IN ACCORDANCE WITH THE BASIC FIBER OPTIC SPECIFICATION, DOD-C-85045.

1.1 PROCUREMENT SPECIFICATION: DOD-C-85045 EXCEPT AS SPECIFIED HEREIN.

1.2 THIS STANDARD IS THE CONTROLLING DOCUMENT AND TAKES PRECEDENCE OVER OTHER DOCUMENTS REFERENCED HEREIN

1.3 REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON DATE OF INVITATION FOR BID OR AS AUTHORIZED BY THE MCAIR STANDARDS ENGINEERING DEPARTMENT.

1.4 VENDORS LISTED HEREIN ARE THE ONLY APPROVED SOURCE. ONLY VENDORS THAT ARE QUALIFIED TO SUPPLY CABLE TO DOD-C-85045 MAY BE CONSIDERED AS A SOURCE OF SUPPLY FOR 5M1945 CABLE AND SHOULD APPLY FOR APPROVAL VIA MCAIR STANDARDS ENGINEERING DEPARTMENT.

2. REQUIREMENTS: FINISHED CABLE SHALL MEET ALL THE REQUIREMENTS OF 5M1945 AND DOD-C-85045. WHERE THERE IS CONFLICT BETWEEN THE TWO DOCUMENTS, 5M1945 SHALL TAKE PRECEDENCE.

2.1 OPTICAL

2.1.1 OPTICAL PROPERTIES SHALL BE AS SPECIFIED IN TABLE II WHEN MEASURED AS REQUIRED IN DOD-C-85045.

2.2 MECHANICAL

2.2.1 MECHANICAL PROPERTIES SHALL BE AS SPECIFIED IN TABLE II WHEN MEASURED AS REQUIRED IN DOD-C-85045

2.3 ENVIRONMENTAL

2.3.1 THERMAL - THE CONTINUOUS TEMPERATURE RANGE IS 125°C TO -55°C.

2.4 MARKING - ALL INTERIOR PACKAGES SHALL BE MARKED PER MIL-STD-129. EACH REEL OF CABLE SHALL BE IDENTIFIED WITH THE FOLLOWING INFORMATION LEGIBLY AND DURABLY PRINTED ON THE REEL.

MCDONNELL'S STANDARD PART NO.	PURCHASE ORDER NO
VENDOR'S NAME	EACH CABLE LENGTH AND TOTAL FOOTAGE
VENDOR'S PART NO.	MCDONNELL CIRCLE NO.
VENDOR'S LOT NO.	
MONTH AND YEAR OF MFGR.	

2.5 QUALITY ASSURANCE

2.5.1 ALL 5M1945 CABLE SHALL MEET THE PERFORMANCE REQUIREMENTS OF TABLE III. GROUP A AND B INSPECTION (EXCEPT JACKET STABILITY AND DURABILITY OF IDENTIFICATION MARKING) IN DOD-C-85045 SHALL BE PERFORMED ON ALL SHIPMENTS OF CABLE TO MCAIR OR MCAIR'S DESIGNEE

2.5.2 CERTIFICATION OF COMPLIANCE SHALL BE PROVIDED WITH EACH LOT.

2.5.3 QUALIFICATION INSPECTION (TABLE II OF DOD-C-85045) SHALL BE PERFORMED BEFORE SHIPMENT OF THE FIRST LOT OF CABLE AND ANYTIME THEREAFTER WHEN MATERIAL OR DIMENSIONS OF THE CONSTRUCTION ARE CHANGED. COPIES OF QUALIFICATION INSPECTION TEST DATA SHALL BE FORWARDED TO MCAIR STANDARDS ENGINEERING DEPARTMENT.

2.5.4 MCAIR RESERVES THE RIGHT TO PERFORM ALL INSPECTIONS AND/OR TESTS TO INSURE COMPLIANCE WITH MIL-C-85045 AND THIS SPECIFICATION AND ACCEPT OR REJECT LOTS IN ACCORDANCE WITH MCAIR'S QUALITY ASSURANCE PROGRAM.

2.6 PREPARATION FOR DELIVERY

2.6.1 THE CABLE SHALL BE SUPPLIED IN MINIMUM LENGTHS OF 500 FEET. REELS OR SPOOLS SHALL BE CONSTRUCTED IN ACCORDANCE WITH PARAGRAPH 5.1.1.1 OF DOD-C-85045. WHEN MORE THAN ONE LENGTH OF CABLE IS PACKAGED ON A REEL, THE ENDS OF EACH LENGTH SHALL BE BROUGHT OUT AND SECURED TOGETHER TO PERMIT CONTINUITY CHECKS ON EACH LENGTH.

2.6.2 THE REQUIREMENTS OF LEVEL A OF MIL-C-12000 SHALL BE MET.

TABLE III
PERFORMANCE REQUIREMENTS

TEST PER DOD STD-1678	RADIATION SOURCE	CENTER WAVELENGTH	SPECT AT BANDWIDTH	SPECIMEN LENGTH	NA OF LAUNCHED RADIATION CONE	TEMP	TIME AT TEMP	MANDREL DIAMETER	MASS	NUMBER OF CYCLES	INCREMENT STATIC FORCE	TIME AT EACH FORCE
ACCEPTANCE PATTERN (6040)	BROAD BAND TUNGSTEN LAMP	900nm	20nm	3,280ft	.32							
POWER TRANSMISSION AT ELEV. TEMP. (4010)				33ft			4 hr.					
POWER TRANSMISSION AFTER HUMIDITY (4020)				33ft								
POWER TRANSMISSION AFTER TEMP. CYCLE (4030)				33ft								
CYCLIC FLEXING (2010)				3.3ft				[illegible] in	[illegible]	[illegible]		
IMPACT TEST (2030)				3.3ft					[illegible]			
TENSILE LOADING (3010)				3.3ft							[illegible] PSI	[illegible] min
COLD BEND (2020)				3.3ft		[illegible]°C	20 hr.	[illegible] in	[illegible]			

	BONDING MATL AND FERRULE	L_1	L_2	RATE OF SPEED OF PWR GRIP	SPECIMEN NO.	TEST FLUID	TEST TEMPERATURE	IMMERSION PERIOD
ELONGATION AND TENSILE STRENGTH FED-STD-228 METH. -3021	AMPHENOL 906 EPOTECH	Shipping Length	1.64 ft.		1	MIL-L-23699, lubricating oil synthetic bas	46-50°C (116-122°F)	20 hrs
ATTENTUATION (6020)		Shipping Length	6.6 ft.		2	MIL-H-5606, hydraulic fluid, petroleum base	48-50°C	20 hrs
					3	TT-I-735, isopropyl alcohol	20-25°C (68-77°F)	168 hrs
JACKET TENSILE STRENGTH AND % ELONGATION (FED STD 228, METH 3021/3031)					4	MIL-T-5624, Grade JP-4, turbine fuel, aviation	20-25°C	168 hrs
					5-6	MIL-A-8243, glycol and anti-icing fluid-undiluted and 60/40 anti-icing fluid/water dilution	48-50°C	20 hrs
					7	MIL-C-43616, cleaning compound aircraft surface-undiluted	48-50°C	20 hrs
CABLE TWIST (2050)	AMPHENOL 906 EPOTECH		6.6 ft.		8	TT-M-268, methyl isobutyl ketone	20-25C	168 hrs
					9	MIL-H-83306, hydraulic fluid, phosphate ester base	48-50C	20 hrs
FLUID IMMERSION (8030)					10	MIL-L-7808, lubrication oil, synthetic base	118-121°C (244-250°F)	5 mnts
					11-12	MIL-C-25769, cleaning compound, aircraft surface-undiluted and diluted with 5 parts water.	63-68°C (145-154°F)	20 hrs
					13-16	TT-S-735, Types I, II, III, VII, hydrocarbon test fluids	20-25°C	168 hrs
					17	Dielectric coolant fluid, synthetic, silicate ester base	20-25°C	168 hrs
					18	Solvent (b) of Method 215, MIL-STD-202	20-25°C	168 hrs
					19	Solvent (c) of Method 215, MIL-STD-202	20-25°C	168 hrs

"Coolanol 25" (Monsanto) or equivalent

1, 1, 1-trichloroethane

"Freon TMC" (Dupont) or equivalent (Azeotrope of dichloromethane and -1, 2, 2-trifluoroethane)

5M1945
SHEET 2

REVISION:

FORM NO. 70301 · APPROVAL DATE: MAY 1980

INFORMATION BELOW THIS LINE NOT PERTINENT TO ENGINEERING DESIGN

APPROVED CALLOUT	APPROVED VENDOR AND VENDOR'S DESIGNATION ▲	SUPERSED PARTS NOT APPROVED FOR PROCUREMENT FOR DISPOSITION DIRECTIONS SEE (6M148)
5M1945-001		NONE

PROCUREMENT REQUIREMENTS
RECEIVING INSPECTION REQUIREMENTS
5M1945 (REV B)

▲ APPROVED VENDOR'S NAME AND FSCM NO

FSCM NO. 76301 . APPROVAL DATE: MAY 1980 REVISION:

5M1945
SHEET 3

GP43-0556-6

APPENDIX C

1760-CS2-1, 1760-CS3-1 - CONTACTS
FIBER OPTIC, SIZE 16, MIL-C-38999,
SERIES I, III AND IV

FED SUP CLASS 6060

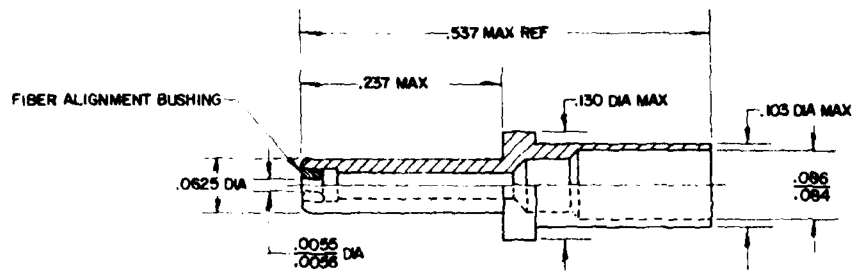

FIGURE C-1 -5M2427-16FOP-PIN CONTACT

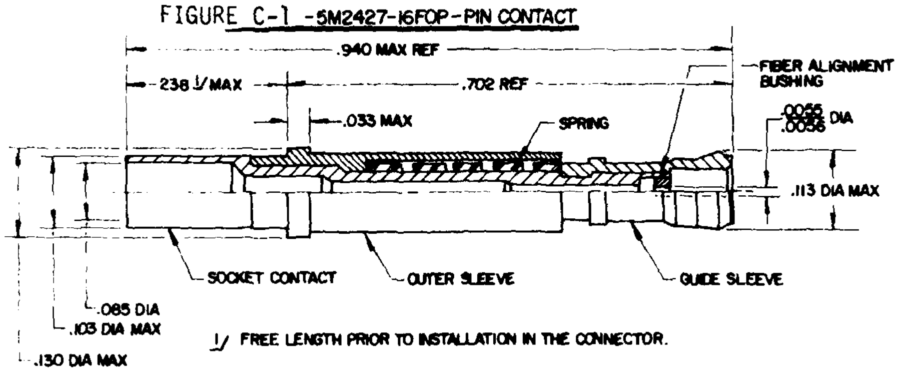

FIGURE C-2 -5M2427-16FOS-SOCKET CONTACT

APPROVED CALLOUT	DESCRIPTION	COMPONENTS, APPROVED CALLOUT	
		CONTACT BODY	ALIGNMENT BUSHING
5M2427-16FOP	PIN	5M2427-001P	5M2427-003B
5M2427-16FOS	SOCKET	5M2427-002S	5M2427-003B

NOTES: 1. GENERAL: THIS SPECIFICATION DESCRIBES THE REQUIREMENTS FOR SIZE 16 FIBER OPTIC CONTACTS FOR USE IN MIL-C-38999 SERIES I, III AND IV CONNECTORS.

1.1 THIS SPECIFICATION IS THE CONTROLLING DOCUMENT AND TAKES PRECEDENCE OVER ALL REFERENCED DOCUMENTS.
1.2 REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON THE DATE OF INVITATION FOR BID OR AS AUTHORIZED IN WRITING BY THE MCAIR STANDARDS ENGINEERING DEPARTMENT.
1.3 VENDORS LISTED HEREIN ARE THE ONLY APPROVED SOURCES. OTHER VENDORS MAY APPLY TO THE MCAIR STANDARDS ENGINEERING DEPARTMENT FOR APPROVAL.
1.4 CABLE ACCOMMODATION: 5M1945-001
1.5 TERMINATION TYPE: EPOXY AND POLISH PER P.S. TBD
1.6 OPTICAL CONNECTION TYPE: FIBER TO FIBER

2. REQUIREMENTS: CONTACTS SHALL MEET THE APPLICABLE REQUIREMENTS OF MIL-C-39029/56, MIL-C-39029/56, MIL-C-38999 AND AS SPECIFIED HEREIN.

2.1 INSERTION LOSS: 1.6 + .6 dB WITH THE CONTACTS INSTALLED IN MIL-C-38999 SERIES I, III OR IV CONNECTORS AND TERMINATED TO 5M1945-001 CABLE PER P.S. TBD.
2.2 MECHANICAL: THE MAXIMUM ALLOWABLE CHANGE IN OPTICAL LOSS SHALL BE 2.7 dB WHEN A MATED PAIR OF CONNECTORS AND CONTACTS ARE TERMINATED TO 5M1945-001 CABLE PER P.S. TBD AND ARE SUBJECTED TO THE TESTS DESCRIBED IN PARAGRAPHS 2.2.1 THROUGH 2.2.4.

2.2.1 MAINTENANCE AGING: 10 CYCLES OF CONTACT INSERTION AND REMOVAL PER METHOD 2002 OF MIL-STD-1344
2.2.2 DURABILITY: 500 MATING CYCLES PER MIL-C-38999
2.2.3 VIBRATION (VERTICAL AXIS): PER MIL-C-38999 SERIES II AND MDC REPORT A3376, SECTION 4.2.H
2.2.4 MECHANICAL SHOCK: PER MIL-C-38999 SERIES II

2.3 ENVIRONMENTAL: THE MAXIMUM ALLOWABLE CHANGE IN OPTICAL LOSS SHALL BE 3.2 dB WHEN A MATED PAIR OF CONNECTORS AND CONTACTS ARE TERMINATED TO 5M1945-001 CABLE PER P.S. TBD AND ARE SUBJECTED TO THE TESTS DESCRIBED IN PARAGRAPHS 2.3.1 THROUGH 2.3.4.

2.3.1 HUMIDITY-TEMPERATURE CYCLING: 10 CYCLES PER METHOD 1002, TYPE II OF MIL-STD-1344
2.3.2 SALT SPRAY: 48 HOURS PER METHOD 1001 OF MIL-STD-1344
2.3.3 THERMAL SHOCK: PER METHOD 1003, CONDITION A OF MIL-STD-1344 (5 CYCLES, -55 C TO 85 C)
2.3.4 SAND AND DUST: PER METHOD 110 OF MIL-STD-202
2.3.5 CORROSION RESISTANCE: PER MIL-C-39029 (48 HOURS SALT)

2.4 MARKING: SHALL BE IN ACCORDANCE WITH MIL-STD-129. UNIT PACKAGE MARKING SHALL INCLUDE THE VENDOR'S NAME, LOGO OR FSCM, VENDOR'S PART NUMBER AND THE MCAIR APPROVED CALLOUT.

DIMENSIONS IN INCHES: TOLERANCES UNLESS OTHERWISE SPECIFIED: .XX ± 0.03; .XXX ± 0.010; ANGLES ± ½°

FSCM NO. 76301	TITLE	CLASSIFICATION
PROCUREMENT SPECIFICATION: NONE	CONTACTS-FIBER OPTIC, SIZE 16, MIL-C-38999 SERIES I, III AND IV (A)	STANDARD PART DOCUMENT
		5M2427
		SHEET 1 OF 2

APPROVAL DATE: JULY 1984 REVISION (A) AUG 84

2.5 QUALITY ASSURANCE:

2.5.1 UNLESS OTHERWISE SPECIFIED, THE CONTRACTOR IS RESPONSIBLE FOR THE PERFORMANCE OF ALL INSPECTION REQUIREMENTS STATED HEREIN AND ANY TESTS HE DEEMS NECESSARY TO ASSURE THAT THE ITEM FURNISHED MEETS THE REQUIREMENTS OF THIS SPECIFICATION AND ALL REFERENCED SPECIFICATIONS.

2.5.2 MCAIR RESERVES THE RIGHT TO PERFORM ANY INSPECTIONS OR TESTS TO INSURE COMPLIANCE WITH THIS SPECIFICATION.

2.6 PREPARATION FOR DELIVERY: SHALL BE IN ACCORDANCE WITH MIL-C-55330.

INFORMATION BELOW THIS LINE IS NOT PERTINENT TO ENGINEERING DESIGN

APPROVED CALLOUT	APPROVED VENDOR AND VENDOR DESIGNATION ▲	SUPERSEDED PARTS NOT APPROVED FOR PROCUREMENT FOR DISPOSITION DIRECTIONS, (SEE 6M148)
5M2427-001P	031-9600-003	NONE
5M2427-002S	031-9599-003	NONE
5M2427-003B	25929Y-3	NONE
5M2427-16FOP 1/		NONE
5M2427-16FOS 1/		NONE

1/5M2427-16FOP and 5M2427-16FOS are contact body and alignment bushing assemblies
See Table I for individual component part numbers.

PROCUREMENT REQUIREMENTS: → 5M2427 (REV A)
RECEIVING INSPECTION REQUIREMENTS: → 5M2427 (REV A)

▲ APPROVED VENDOR'S NAME AND FSCM NO.: ITT CANNON, FOUNTAIN VALLEY, CA (71468)

REVISION: (A) AUG 84

FSCM NO. 76301 . APPROVAL DATE: JULY 1984

5M2427
SHEET 2

APPENDIX D

1760-CS2-2, 1760-CS3-2 - CONTACTS
FIBER OPTIC, SIZE 16,
MIL-C-38999, SERIES I, III AND IV

FED SUP CLASS 6060

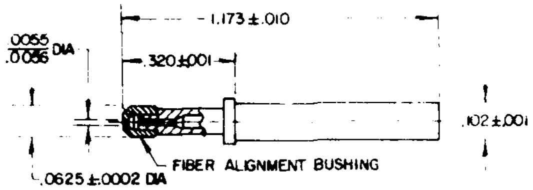

FIGURE D-1 -5M2428-16FOP PIN CONTACT

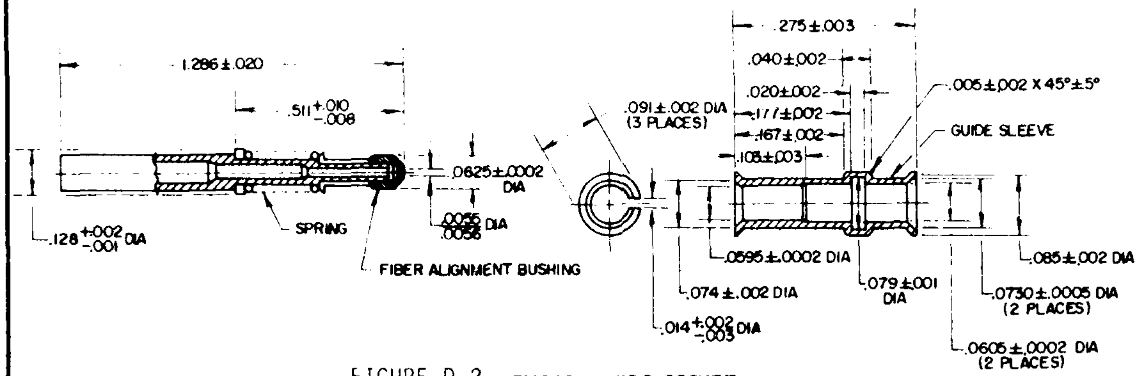

FIGURE D-2 -5M2428-16FOS-SOCKET

NOTES 1 GENERAL THIS SPECIFICATION DESCRIBES THE REQUIREMENTS FOR SIZE 16 FIBER OPTIC CONTACTS FOR USE IN MIL-C-38999 SERIES I, III AND IV CONNECTORS

1.1 THIS SPECIFICATION IS THE CONTROLLING DOCUMENT AND TAKES PRECEDENCE OVER ALL REFERENCED DOCUMENTS
1.2 REFERENCED DOCUMENTS SHALL BE OF THE ISSUE IN EFFECT ON THE DATE OF INVITATION FOR BID OR AS AUTHORIZED IN WRITING BY THE MCAIR STANDARDS ENGINEERING DEPARTMENT
1.3 VENDORS LISTED HEREIN ARE THE ONLY APPROVED SOURCES OTHER VENDORS MAY APPLY TO THE MCAIR STANDARDS ENGINEERING DEPARTMENT FOR APPROVAL
1.4 CABLE ACCOMMODATION 5M1945-001
1.5 TERMINATION TYPE EPOXY AND POLISH PER P.S. TBD
1.6 OPTICAL CONNECTION TYPE FIBER TO FIBER

2 REQUIREMENTS CONTACTS SHALL MEET THE APPLICABLE REQUIREMENTS OF MIL-C-39029/56, MIL-C-39029/58, MIL-C-38999 AND AS SPECIFIED HEREIN

2.1 INSERTION LOSS 1.6 + .5 dB WITH THE CONTACTS INSTALLED IN A MIL-C-38999 SERIES I, III OR IV CONNECTORS AND TERMINATED TO 5M1945-001 CABLE PER P.S. TBD
2.2 MECHANICAL THE MAXIMUM ALLOWABLE CHANGE IN OPTICAL LOSS SHALL BE 2.7 dB WHEN A MATED PAIR OF CONNECTORS AND CONTACTS ARE TERMINATED TO 5M1945-001 CABLE PER P.S. TBD AND ARE SUBJECTED TO THE TESTS DESCRIBED IN PARAGRAPHS 2.2.1 THROUGH 2.2.4

2.2.1 MAINTENANCE AGING [illegible] CYCLES [illegible] CONTACT INSERTION AND REMOVAL PER METHOD 2002 OF MIL-STD-1344
2.2.2 DURABILITY 500 MATING CYCLES PER MIL-C-38999
2.2.3 VIBRATION (VERTICAL AXIS) PER MIL-C-38999 SERIES II AND MDC REPORT A1176, SECTION 4.2.[illegible]
2.2.4 MECHANICAL SHOCK PER MIL-C-38999 SERIES II

2.3 ENVIRONMENTAL THE MAXIMUM ALLOWABLE CHANGE IN OPTICAL LOSS SHALL BE 3.7 dB WHEN A MATED PAIR OF CONNECTORS AND CONTACTS ARE TERMINATED TO 5M1945-001 CABLE PER P.S. TBD AND ARE SUBJECTED TO THE TESTS DESCRIBED IN PARAGRAPHS 2.3.1 THROUGH 2.3.4

2.3.1 HUMIDITY-TEMPERATURE CYCLING [illegible] CYCLES PER METHOD 1002, TYPE II OF MIL-STD-1344
2.3.2 SALT SPRAY 48 HOURS PER METHOD 1001 OF MIL-STD-1344
2.3.3 THERMAL SHOCK PER METHOD 1003, COND[ITION] A OF MIL-STD-1344 [illegible] CYCLES, -55 [illegible] 85 [illegible]
2.3.4 SAND AND DUST PER METHOD 510 OF MIL-STD-202
2.3.5 CORROSION RESISTANCE PER MIL-C-39029 48 HOURS SALT

2.4 MARKING SHALL BE IN ACCORDANCE WITH MIL-STD-129 UNIT PACKAGE MARKING SHALL INCLUDE THE VENDOR'S NAME, LOGO OR FSCM, VENDOR'S PART NUMBER AND THE MCAIR APPROVED [illegible]

2.5 QUALITY ASSURANCE

2.5.1 UNLESS OTHERWISE SPECIFIED, THE CONTRACTOR IS RESPONSIBLE FOR THE PERFORMANCE OF ALL INSPECTION REQUIREMENTS STATED HEREIN AND ANY TESTS HE DEEMS NECESSARY TO ASSURE THAT THE ITEM FURNISHED MEETS THE REQUIREMENTS OF THIS SPECIFICATION AND ALL REFERENCED SPECIFICATIONS

DIMENSIONS IN INCHES: TOLERANCES UNLESS OTHERWISE SPECIFIED: .XX ± 0.03; .XXX ± 0.010; ANGLES ± ½°

FSCM NO. 76301		**CLASSIFICATION**
PROCUREMENT SPECIFICATION NONE	**TITLE** CONTACTS-FIBER OPTIC, SIZE 16, MIL-C-38999 SERIES I, III AND IV	**STANDARD PART DOCUMENT**
		5M2428 SHEET 1 OF 2

REVISION:

APPROVAL DATE JULY 1984

6.3.2 Identification - All identification and marking of cables and harnesses will be done in accordance with the requirements of MIL-W-5088 and this specification.

6.4 CLEANING OF POLISHED FIBER ENDS

6.4.1 Polished fiber ends shall be cleaned by any of the following methods:

6.4.1.1 Dipping the contact end into an ultrasonic cleaning tank (Paragraph 4.1.1) of Freon TF (Paragraph 3.2.1) for a minimum of 10 seconds.

6.4.1.2 Spraying the contact end with Freon TF (Paragraph 3.2.2).

6.4.1.3 Dipping the contact end into alcohol (Paragraph 3.2.3).

6.4.2 In all cleaning methods, the polished fiber end shall be allowed to air dry for 30 seconds or longer. If available, wipe the polished fiber end with optical wiping tissue (Paragraph 3.2.4) immediately after cleaning.

6.5 PROTECTION OF POLISHED FIBER ENDS

6.5.1 Polished fiber ends shall be protected by any of the following:

6.5.1.1 Plastic dust cap (Paragraph 3.2.7)

6.5.1.2 Polyethylene bag (Paragraph 3.2.8)

6.5.1.3 Other device which provides protection from damage or contamination.

7.0 QUALITY ASSURANCE PROVISIONS

7.1 PROCESS CONTROL - Maintain surveillance as necessary to ensure compliance to the following:

7.1.1 Visually inspect (up to 40X magnification) to ensure that the surface of the contact and fiber is flat and free of scratches or gross imperfections, and that the fiber is not chipped.

7.2 ACCEPTANCE INSPECTION

7.2.1 Visually inspect the harness to verify there are no lump(s) on the harness due to foreign object(s) under the braid.

7.2.2 Visually inspect the termination to verify that the cured epoxy exhibits proper adhesion between the fiber and the contact.

7.2.3 Visually inspect the cable and terminated ends for damage - nicks, scratches, contamination, etc.

7.2.4 All cables with a termination at each end shall be measured with the OATS (Paragraph 4.2.2) to verify that losses do not exceed the values given in Table F-3, in either direction. Reject all cables that fail to meet this requirement. (When there is a larger than 0.5dB difference in the measurement for

6.1.6 Socket Contact Assembly (Figure F-2)

6.1.6.1 1760-CS3-1 - After the polishing is complete, insert the spring into the outer sleeve from the end opposite the shoulder. Then slide these parts over the terminated socket contact, shoulder end first. The small end of the guide sleeve is then pressed on, captivating the assembly. Apply slight tension to the guide sleeve to verify assembly captivation.

6.1.6.2 1760-CS3-2 - The socket contact spring has been factory installed. The long end of the guide sleeve is pressed onto the terminated socket contact until it seats against the socket contact shoulder.

6.2 CONTACT INSERTION INTO CONNECTOR

6.2.1 Assemble the components for the socket contact as shown in Figure F-2.

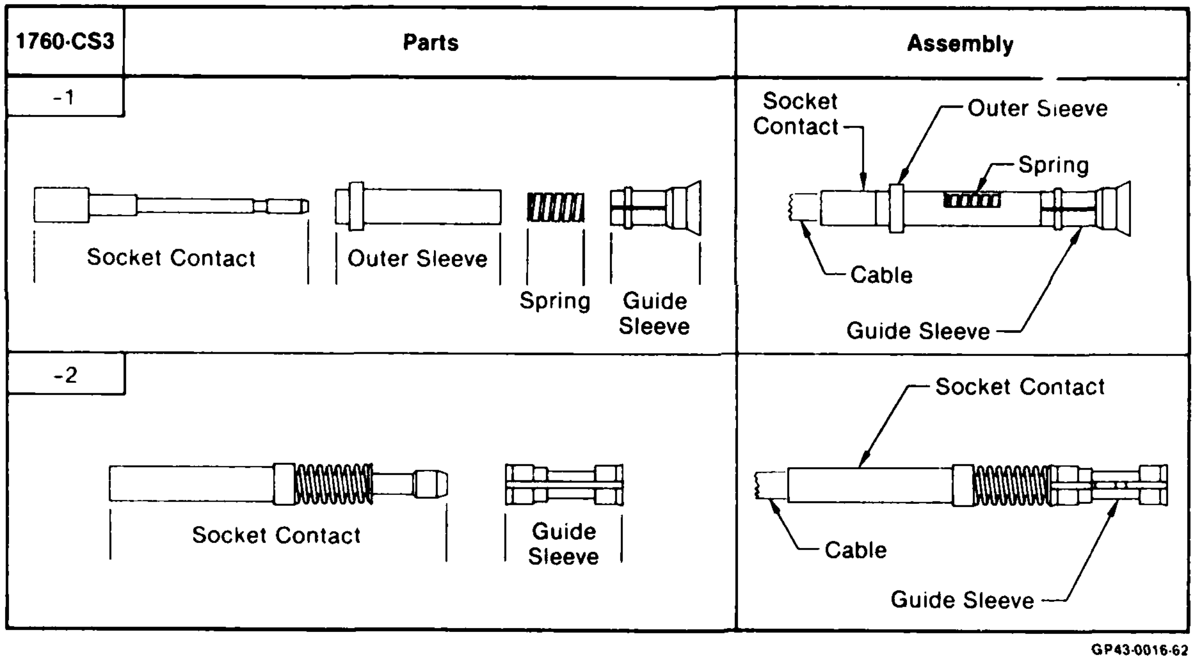

Figure F-2. Socket Contact Assembly

Note: Prior to insertion, use a dip or spray of Freon TF (Paragraph 3.2.1 or 3.2.2) on the contact and dry with heat (Paragraph 4.1.6) or optical wiping tissue (Paragraph 3.2.4).

6.2.2 Insert the cable/contact assembly into the connector cavity with a Paragraph 4.1.7 insertion tool. Apply tension to the cable to ensure that the assembly is locked in place.

6.3 HARNESS FABRICATION

6.3.1 Routing - Route fiber optics cables per drawings.

TABLE F-2. EPOXY CURE SCHEDULE

Minimum Time (hr)	Temperature ±10°F
1/2	300*
2	250

*A heat gun (Paragraph 4.1.7) may be used if the temperature is monitored to ±25°F. With the nozzle vents open, the temperature should be 300°F about 1-1/2 – 2 inches from the nozzle end

Caution: Exercise Care That Heat From the Heat Gun Is Not Directed at Heat Sensitive Materials or Parts in Adjacent Areas.

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6.1.5 Fiber End Finish

6.1.5.1 Carefully cut or break off the excess fiber at the surface of the epoxy bead leaving 1/16 inch or more to be ground off. For this operation, nail clippers or their equivalent may be used to cut the protruding fiber, or the fiber may be broken off by simply bending the fiber with your fingers.

6.1.5.2 Insert the contact into the polishing fixture (Paragraph 4.1.5) so that the untrimmed fiber will extend beyond the fixture face.

6 1.5.3 Position a blue polishing sheet (Paragraph 3.2.6) on a flat surface and apply clean tap water over the area to be utilized. Water is necessary as a lubricant.

6.1.5.4 Move the fixture assembly in a long figure eight motion until a thin layer of epoxy just covers the end face. Flush the fiber end, polishing fixture, and work area with clean water.

6.1.5.5 Turn the polishing fixture so that the polishing direction is perpendicular to the prior polishing direction. Using yellow polishing sheets, polish the end of the fiber until all scratch marks have been removed. Flush the fiber end, polishing fixture, and work area with clean water.

6.1.5.6 Repeat step 6.1.5.5 using pink polishing sheets.

6.1.5.7 Repeat step 6.1.5.5 using violet polishing sheets. Verify that the contact or fiber does not protrude past the fixture by drawing a straight edge across the face of the polishing fixture.

6.1.5.8 Wash the contact tip using clean water and clean it ultrasonically using Freon (Paragraph 3.2.1). If the ultrasonic tank is not available use a dip or spray of Freon TF (Paragraph 3.2.2). Dry the contact with heat (Paragraph 4.1.6) or cotton cloth wipers (Paragraph 3.2.5).

6.1.5.9 Examine the fiber end for gross imperfections using 40X magnification (Paragraph 4.2.1). Be sure the optical surface is flat and free of scratches, chips or epoxy smears. If necessary, repeat the latter polishing steps.

6.1.2 Cleaning - Clean the portions of the cable and the connector parts to be epoxied by dipping them in an ultrasonic cleaning tank (Paragraph 4.1.1) of liquid Freon TF (Paragraph 3.2.1). If not available, use Freon TF spray (Paragraph 3.2.2). Wipe the fiber clean with tissue (Paragraph 3.2.4 or 3.2.5), and allow it to dry for 30 seconds or longer.

6.1.3 Epoxy Mixing

CAUTION: Avoid epoxy contact with the skin and eyes, and use in a well ventilated area.

6.1.3.1 Elevated Cure Epoxy - Mix equal parts by weight of the two part epoxy (Paragraph 3.1.1) in a clean glass, stainless steel, paper or polyethylene container. Stir thoroughly with a clean wood, glass or stainless steel stirrer. The mixed pot life is 8 hours or longer. Keeping the container closed when the epoxy is not being used will extend its pot life. Scrap the material when it starts to gel. Use the Paragraph 3.1.1 epoxy for general production.

6.1.3.2 Premeasured 2 Pouch Kit, Elevated Temperature Cure Epoxy - Remove the separator from the premeasured 2 pouch kit (Paragraph 3.1.2). Knead the epoxy thoroughly to mix while still in the packet. To dispense, cut off a corner of the package. The mixed pot life is 8 hours or longer. Scrap the material when it starts to gel. Use Paragraph 3.1.2 epoxy where only a few terminations are to be made.

6.1.4 Epoxy Application

6.1.4.1 Install the hypodermic needle (Paragraph 4.1.2) on the syringe (Paragraph 4.1.3). Fill the syringe with epoxy. Hold the syringe with the needle pointed upward so the air bubbles rise to the surface. Force the air bubbles out of the syringe through the needle. Insert the syringe into the rear of the contact as far as possible and slowly fill the contact half full. (Take care not to get air bubbles in the contact.) Epoxy should come through the hole at the end of the contact.

6.1.4.2 Wrap a strip of Teflon or other non-adhesive material around the strength member to hold it down. Slide the contact over the stripped cable, rotating the contact until the fiber finds the hole. Work the Teflon back as the braid goes into the contact. When all but 0.1 inch of fiber is protruding from the end of the contact, the cable is properly seated.

Note: Ensure that the strength member is not bunched at the base of the contact.

6.1.4.3 Apply a drop of epoxy at the fiber tip and clean the exterior of the contact of excess epoxy with a wiper (Paragraph 3.2.4).

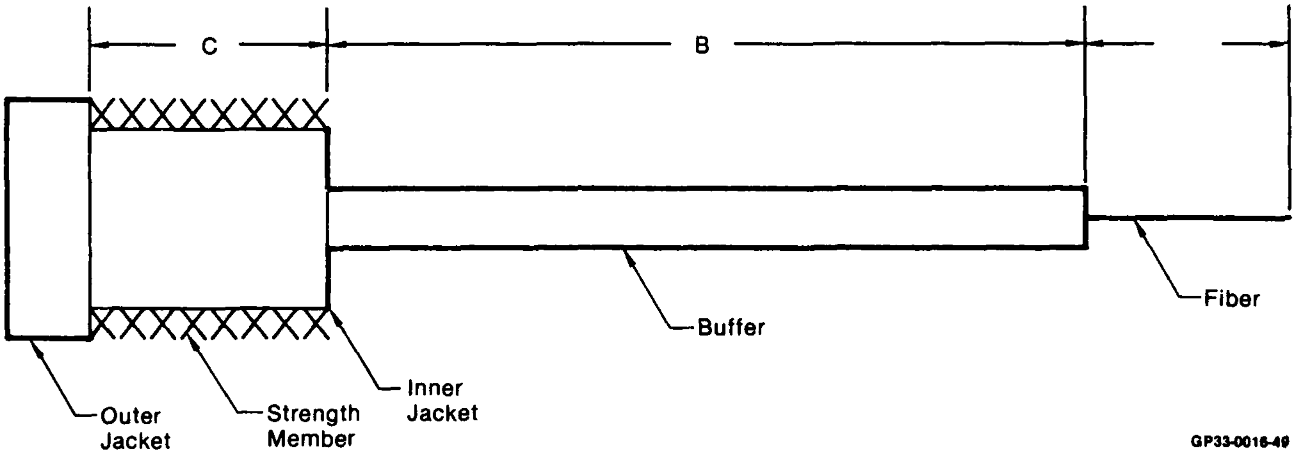
6.1.4.4 Cure the assembly in an air circulating oven (Paragraph 4.1.4) in accordance with Table F-2. The assembly shall be in a horizontal position during curing.

5.3.6 Unbraided harness - Plastic cable straps per MIL-W-5088 shall be used as the secondary support to form the harness and to secure breakouts. The straps shall be spaced at intervals not greater than 12 inches.

6.0 PROCEDURES

6.1 CABLE TERMINATION - FIGURE F-1

6.1.1 Trim the cable to the dimensions shown in Figure F-1 with the tools listed in Table F-1.



Contact Number	Type	Strip Dimensions (in.) A	B	C
1760-CS2-1	Pin	0.300	0.150	0.187
1760-CS3-1	Socket	0.300	0.470	0.167
1760-CS2-2	Pin	0.625	0.500	0.140
1760-CS3-2	Socket	0.500	1.250	0.375

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Figure F-1. Cable Strip Dimensions

TABLE F-1. TOOLS FOR STRIPPING

Cable Component to Be Removed	Stripping Method
Outer Jacket	Paragraph 4.1.8, 4.1.9, or 4.1.10
Braid	Scissors or Equivalent
Inner Jacket	Paragraph 4.1.11 or 4.1.12
Buffer	Paragraph 4.1.13 or 4.1.14

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5.0 REQUIREMENTS

5.1 GENERAL

5.1.1 When a fiber optics cable is routed within a wire harness, the harness shall meet the requirements of MIL-W-5088.

5.2 CABLE TERMINATION

5.2.1 Jacket Stripping - The jacket shall be removed to expose the fiber without damaging the fiber.

5.2.2 Cleanliness - The jacket, fibers and contacts which are joined with epoxy shall be clean and dry prior to epoxy application.

5.2.3 Epoxy Application - Do not entrap air during epoxy fill of contact.

5.2.4 Fiber End Finish - The fiber shall be centered in the contact end, the surface flat with a minimum of scratches and chips and exhibiting adhesion to the contact. The fiber/contact shall not protrude from the face of the polishing fixture.

5.2.5 Allowable Losses - The losses in the cable shall be measured per Paragraph 7.2.4. Reject any cable whose losses exceed the values given in Table F-3. A cable with terminations on each end must meet this requirement in both directions.

5.2.6 Polished Fiber Protection - The polished fiber ends shall be protected from damage or contamination.

5.2.7 Mating - Polished fiber ends shall be cleaned immediately prior to mating with other components. EXCEPTION: In a clean room, the polished ends may be left unprotected for up to one hour prior to mating, without recleaning.

5.3 HARNESS FABRICATION

5.3.1 General - All braiding and shielding procedures will conform to present methods used on standard electrical interconnect systems.

5.3.2 Harness Length - The length tolerance in completed fiber optics harnesses shall be +0.5, -0.0 inch.

5.3.3 Branches - The branch break-out tolerance shall be ±0.50 inch from the position shown on the harness board.

5.3.4 Splices - Fiber optics cable shall be spliced only when authorized by Engineering. Replace the cable when the jacket damage exceeds superficial nicks or scuffing or when allowable losses are exceeded.

5.3.5 Radius of Bend - Wiring bend radii shall comply with the requirements of MIL-W-5088, with the exception that for an individual fiber optics cable, the minimum bend radius allowable is ten times the outside diameter of the cable.

4.0 EQUIPMENT AND FACILITIES

4.1 PROCESS EQUIPMENT

4.1.1 Cleaning tank, ultrasonic, Ultromet 75-1970-115-A8 or equivalent.

4.1.2 Hypodermic needle, Yale 18 gage, 1-1/2 inches long, Becton-Bickinson Co. (used with item defined in Paragraph 4.1.3)

4.1.3 Syringe, disposable, 5cc, #156-000, Curtin Co.

4.1.4 Oven, air circulating, 150°F-300°F ± 10°

4.1.5 Fixture, polishing

(a) 317-1774-000, ITT-Cannon, Santa Ana, CA 92702 for 1760-CS2-1 and 1760-CS3-1

(b) L-36251-321, Amphenol Products, Sidney, NY 13838 for 1760-CS2-2 and 1760-CS3-2

4.1.6 Heat gun, 300°F-500°F ± 10° - HG 301, Master Appliance, Racine, WC.

4.1.7 Insertion/removal tool, M81969/14-03

4.1.8 Stripper, blade, 45-176 with L-5559 blade set - Ideal Industries Inc.

4.1.9 Stripper, blade, 45-162 with L-9225 blade - Ideal Industries Inc.

4.1.10 Blade, razor or exacto type

4.1.11 Stripper, blade, 45-176 with L-4994 blade set - Ideal Industries Inc.

4.1.12 Stripper, blade, No-nik, 0.0201 cutting range, royal blue, Clauss Cutlery Co., Fremont, Ohio.

4.1.13 Stripper, blade, model MS, Micro-strip 0.008, Utica Tool Co. Inc.

4.1.14 Stripper, blade, No-nik, 0.010 cutting range, light blue, Clauss Cutlery Co., Fremont, Ohio.

4.2 QUALITY ASSURANCE EQUIPMENT

4.2.1 Magnifier, 20-40x

4.2.2 Optical Attenuation Test Set (OATS)

(a) UDT #S550, United Detector Technology, Culver City, CA 90230

(b) Wilcom #T312B, Wilcom Products Inc., Laconia, NH 03246

4.2.3 Optical Time Domain Reflectometer (OTDR), Resolution - 40cm, Probe Pulse Width - 4ns FWHM, Probe, Pulse Return - 1ns, OPTIXX Model 401.

INTERCONNECT, FIBER OPTICS, FABRICATION OF MIL-STD-1760

1.0 APPLICATION

1.1 This specification defines the procedure for the fabrication of a MIL-STD-1760 fiber optics interconnect system. It contains only the procedures which are unique to fiber optics. All other standard MIL-W-5088 electrical interconnect procedures will be utilized.

1.2 This specification is applicable when specified on the Engineering drawings and other process specifications or applicable documents.

2.0 APPLICABLE DOCUMENTS

2.1 ISSUES OF DOCUMENTS - The following document, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

MIL-W-5088 Wiring, Aerospace Vehicle.
FOTP-59A General Descriptions of Optical Time Domain Reflectometry, EIA.

3.0 MATERIALS AND/OR SOLUTIONS

3.1 END ITEMS MATERIALS

3.1.1 Epoxy, elevated temperature cure, two part - 1760-MS1

3.1.2 Epoxy, elevated temperature cure, 2 Part, premeasured 4 gram pouch kit, 1760-MS1.

3.2 OTHER MATERIALS

3.2.1 Solvent, Freon TF, liquid, MIL-C-81302.

3.2.2 Solvent, Freon TF, pressurized spray container, MIL-C-81302.

3.2.3 Solvent, alcohol, isopropyl, FED TT-I-735.

3.2.4 Tissue, optical wiping - Kodak #154-6027 or equivalent.

3.2.5 Cotton cloth wipers - cheesecloth, commercial

3.2.6 Polishing sheets, adhesive backed, Color/Micron -- Blue/40, Yellow/12, Pink/3, Violet/1. Imperial PSA Lapping Film Sheets, 3M Co., Minneapolis, MN.

3.2.7 Caps, dust, plastic, MS90376

3.2.8 Bags, polyethylene, various sizes

APPENDIX F

1760-PS1 - INTERCONNECT, FIBER OPTICS,
FABRICATION OF MIL-STD-1760

7.4 DELIVERY PREPARATION

7.4.1 The material components may be supplied in bulk in two separate containers or in premeasured kits which provide a method of mixing within the supplied kit.

7.4.2 Each kit or component container shall be marked as follows:

(a) Manufacturer's number
(b) Date of manufacture or date from which 1 year shelf life remains.

8.0 SAFETY

8.1 The material does not contain any solvents or thinners.

TABLE E-1. QUALIFICATION REQUIREMENTS

Requirement	Procedure	Criteria
Hardness	ASTM D2240, Shore D	80 Minimum
Viscosity	ASTM D1200	400 CPS
LAP Shear Strength	ASTM D707, 20 mm/min	2,400 psi
Moisture Absorption	ASTM D570, Water Immersion, 250 hr @ 32°C	0.05% Maximum
Shrinkage	4 hr @ 160°C, 1/8 in. Dia Bar	0.05 in./in. Maximum
Thermal Coefficient of Linear Expansion	ASTM D3386	25.0×10^{-6} in./in./°C Maximum
Gloss Transition Temperature	120°C for 1 hr	102° to 110°C
Heat Distortion 66 psi Stress	ASTM D648	175°C
Thermal Shock	MIL-STD-202, Method 107B, −60° to +125°C	No Cracking, Meet Shrinkage Requirement
Hydrolytic Stability	MIL-I-16923	10% Maximum Drop in Shore D Hardness

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5.3 PHYSICAL REQUIREMENTS

5.3.1 Mix Ratio - The material shall be prepared by mixing two component materials together with a mix ratio of one to one by weight.

5.3.2 Color - The color of the mixed material shall be amber.

5.3.3 Pot life - The mixed pot life of the material shall be at least 8 hours at 24°C $\pm$ 2°.

5.3.4 Cure - In a thin film, the mixed material shall cure as follows:

30 minutes @ 150°C
60 minutes @ 120°C

5.3.5 Temperature Rating - The continuous operating range of the mixed, cured material shall be from -55°C to +160°C.

5.3.6 Test Requirements - The mixed, cured material shall meet the test requirements of Table E-1.

5.3.7 Shelf Life - Unopened containers of the two component parts shall be capable of meeting all of the requirements of this specification after storage for up to one year at 10°C to 40°C.

6.0 PROCEDURE

Not applicable.

7.0 QUALITY ASSURANCE PROVISIONS

7.1 VENDOR QUALIFICATION

7.1.1 The vendor is responsible for the performance of all test and inspection requirements as specified herein. All substantiating and qualification test data shall be certified by the vendor, if specified by the purchaser.

7.1.2 Failure of a product to meet all of the requirements and quality assurance provisions of this specification shall be cause for rejection of the material, disapproval of a vendor, or removal of a vendor from the approved products list.

7.2 ACCEPTANCE INSPECTION PROVISIONS

7.2.1 Production shipments of qualified material shall be tested to determine compliance with this specification. Acceptance tests shall consist of those tests deemed necessary by Quality Assurance to maintain quality.

7.3 TEST METHODS

7.3.1 Use those test methods specified in Table E-1.

TWO PART ELEVATED CURE FIBER OPTICS EPOXY

1.0 APPLICATION

1.1 This specification establishes the requirements for a two part epoxy for fiber optics terminations which requires elevated temperature curing. The continuous service temperature rating is: -60°C to +125°C.

2.0 APPLICABLE DOCUMENTS

2.1 The following documents, the latest revisions in effect on the date of invitation to bid, except as otherwise noted, form a part of the specification to the extent specified herein.

ASTM D570	Test Method for Water Absorption of Plastics
ASTM D648	Test Method for Deflection Temperature of Plastics Under Flexural Load
ASTM D797	Test Method for Rubber Property - Young's Modulus at Normal and Subnormal Temperatures
ASTM D1200	Viscosity of Paints, Varnishes, and Lacquers by Ford Viscosity Corp.
ASTM D2240	Test Method for Rubber Property - Durometer
MIL-STD-202	Method 107B Test Methods for Electronic and Electrical Component parts - Thermal Shock
MIL-I-16933	Insulating Compound, Electrical, Embedding

3.0 MATERIALS AND/OR SOLUTIONS

Not applicable.

4.0 EQUIPMENT AND FACILITIES

Not applicable.

5.0 REQUIREMENTS

5.1 QUALIFICATION - The epoxy furnished under this specification shall be a product which meets all of the requirements of this specification, which has been tested and has passed the qualification tests specified herein, and which is listed as an approved product.

5.2 MATERIAL AND MANUFACTURE - Products conforming to this specification shall be manufactured in accordance with the best commercial practices using high quality ingredient materials.

APPENDIX E

1760-MS1 - TWO PART ELEVATEAD
CURE FIBER OPTICS EPOXY

2.5.2 MCAIR RESERVES THE RIGHT TO PERFORM ANY INSPECTION OR TESTS TO INSURE COMPLIANCE WITH THIS SPECIFICATION.

2.6 PREPARATION FOR DELIVERY: SHALL BE IN ACCORDANCE WITH MIL-C-55330.

INFORMATION BELOW THIS LINE IS NOT PERTINENT TO ENGINEERING DESIGN

APPROVED CALLOUT	APPROVED VENDOR AND VENDOR DESIGNATION ▲	SUPERSEDED PARTS NOT APPROVED FOR PROCUREMENT FOR DISPOSITION DIRECTIONS, (SEE 6M148)
5M2428-16FOP	CF-198014-7	NONE
5M2428-16FOS	CF-198013-7	NONE

PROCUREMENT REQUIREMENTS
RECEIVING INSPECTION REQUIREMENTS
5M2428 DATED JULY 1984

▲ APPROVED VENDOR'S NAME AND (FSCM NO.) BENDIX CORP., SIDNEY, NY (77820)

REVISION:

FSCM NO. 76301 . APPROVAL DATE: JULY 1984

5M2428

SHEET 2

MAC 3400 (REV 13 MAY 77)

the two directions, a fault at one of the connector ends can usually be found.) Use an OTDR (Paragraph 4.2.3) to locate the fault.

TABLE F-3. ACCEPTANCE CRITERIA

Test	Acceptance Criteria
Cable Loss	— 2 dB Maximum for a Single Cable Segment. — Allow an Additional 3 dB for Each Cable Segment Added in Series, That Is, 2 Cables in Series - 5 dB Maximum, 3 Cables in Series - 8 dB Maximum, etc.

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7.2.5 Reject all cables with unauthorized splices or connectors.

8.0 SAFETY

8.1 GENERAL PRECAUTIONS

8.1.1 First Aid - In event of eye or skin contamination by solvents:

8.1.1.1 Flush the exposed area with large amounts of water.

8.1.1.2 Remove contaminated clothing.

8.1.1.3 Secure first aid immediately.

8.1.2 Toxicology - Avoid prolonged breathing of solvent vapors. If this is impossible, wear a respirator. Respirators used must be approved by the Safety and Medical Department.

8.1.3 Fire Hazard - Do not use solvents in the vicinity of smoking, sparks or open flames. Flammable solvents are extremely easy to ignite and fires may occur with explosive violence. After using flammable solvents, be certain that no traces linger on clothes or person before leaving a no-smoking area.

8.1.4 Handling and Storage

8.1.4.1 Wear safety glasses (or goggles) and rubber gloves while working with solvents.

8.1.4.2 Do not smoke while working with flammable solvents or while in a no-smoking area.

8.1.4.3 Bare filament heaters or other sources of ignition, including metal objects on shoes, are prohibited in flammable solvent areas. Electrical equipment, including flashlights, shall be explosion proof. Avoid any action which may create sparks, including dragging of steel drums, metal work stands, or similar objects, across a concrete floor.

8.1.4.4 If a part to be cleaned by a cloth wetted with flammable solvent has an area to be cleaned exceeding one square foot, that part shall be electrically grounded.

8.1.4.5 Isolate flammable solvent storage areas from areas of fire hazard. Electrically ground all equipment in the storage area. Electrically bond dispensing and receiving containers to each other while transferring flammable solvents between the containers.

8.1.4.6 Store and handle solvents in properly labelled safety containers. Keep all containers closed while not in use.

8.1.4.7 Store solvents in cool, well ventilated areas.

8.1.4.8 Do not use solvents in confined areas unless specifically authorized. Ensure that adequate ventilation is provided; the fumes are generally toxic, flammable, and explosive.

8.1.4.9 Limit the quantity of flammable solvents in working areas to a one-day supply.

8.1.4.10 Ensure that parts which have been wetted with solvents are completely dry prior to further processing. Unless specifically authorized, the use of heat producing devices to accelerate drying is prohibited.

8.1.4.11 Dispose of all rags in flammable solvent areas in special containers designated for that purpose.

8.2 SOLVENTS

8.2.1 Freon TF - clear, colorless, nonflammable and moderately toxic.

8.2.2 Isopropyl alcohol - clear, colorless, moderately flammable and moderately toxic.

8.3 NONSOLVENT MATERIALS

8.3.1 EPO-TEK 377 - not a fire hazard, but is toxic.

8.4 GLASS FIBERS

8.4.1 Broken pieces of glass fiber shall not be permitted to remain loose in the work area.

APPENDIX G

1760-PS2 - INTERCONNECT,
FIBER OPTICS, MIL-STD-1760,
INSTALLATION OF AIRCRAFT

INTERCONNECT, FIBER OPTICS, MIL-STD-1760, INSTALLATION OF AIRCRAFT

1.0 APPLICATION

1.1 This specification defines the procedures for the installation of a MIL-STD-1760 fiber optics interconnect system. It contains only the procedures which are unique to fiber optics. All other MIL-W-5088 installation procedures for standard electrical interconnect will be utilized.

1.2 This specification is applicable when specified on the Engineering drawings and other process specifications or applicable documents.

2.0 APPLICABLE DOCUMENTS

2.1 ISSUES OF DOCUMENTS - The following documents, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

(a) MIL-W-5088 Wiring, Aerospace Vehicle

(b) MIL-C-38999 Connector, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded and Breech Coupling), Environmental Resistant, Removable Crimp and Hermetic Solder Contacts, General Specifications For

3.0 MATERIALS AND/OR SOLUTIONS

3.1 Laboratory clean gas

(a) Micro Duster Kit #TX600 (214-31369)
(b) Micro Duster Refill #TW104 (200-75410)
Texwipe Company, Upper Saddle River, NJ

3.2 Solvent, Freon TF, pressurized spray container, MIL-C-81302

3.3 Solvent, alcohol, isopropyl, TT-I-735

3.4 Tissue, optical wiping - Kodak #154-6027 or equivalent

3.5 Caps, dust, plastic, MS90376, various sizes

3.6 Bags, polyethylene, various sizes

4. EQUIPMENT AND FACILITIES

4.1 QUALITY ASSURANCE EQUIPMENT

4.1.1 Flashlight, 2 Cell, "D" battery size

4.1.2 Optical Attenuation Test Set (OATS)

(a) UDT #S550, United Detector Technology, Culver City, CA 90230.
(b) Wilcom #T312B, Wilcom Products Inc., Laconia, NH 03246.

4.1.3 Optical Time Domain Reflectometer (OTDR), suitable for cables less than 30 feet in length, OPTIXX Model 401, or equivalent.

5.0 REQUIREMENTS

5.1 PROCESSING REQUIREMENTS

5.1.1 Fiber optics cables shall not be kinked, folded or crushed during handling or installation. Over-stressing of a copper cable will cause degradation; overstressing of a fiber optics cable will result in complete failure.

5.1.2 Cables and harnesses shall be installed in a neat and orderly manner.

5.1.3 Connectors

5.1.3.1 Cleaning - Prior to mating connectors, ensure that the connectors are undamaged, free from dirt, chips, and foreign matter. Immediately prior to mating, the fiber end shall be solvent cleaned and dried per Paragraph 6.2. If the connectors have been unmated only momentarily and have been kept clean, the solvent cleaning may be omitted.

5.1.3.2 Protection - Unmated connectors shall be protected from damage or contamination.

5.2 END ITEM REQUIREMENTS

5.2.1 Harnesses - When a fiber optics cable is routed within a wire harness, the harness shall meet the requirements of MIL-W-5088 except as noted herein.

5.2.2 Cable Slack - In addition to drip loop requirements, minimum slack shall be left in cables to meet the following requirements:

5.2.2.1 Provide ease of maintenance.

5.2.2.2 Prevent mechanical strain on cables, cable junctions and cable supports.

5.2.2.3 Provide free movement of shock and vibration mounted equipment.

5.2.2.4 Provide servicing of cockpit console control panels without disturbing any other control panels.

5.2.2.5 Allow a minimum of 1-1/2 inches of slack for connector replacement. This slack shall be between the connector and the second wiring support clamp. That is, with the connector unmated and the first clamp loosened, the cable will permit the front end of the connector shell to extend 1-1/2 inches beyond the point normally required to properly mate the connector. Cable routing shall accomodate the slack without cable fold back.

5.2.3 Cable Bend Radius - When it is necessary to bend a cable or harness, the bend radius shall be as large as is feasible and shall be a minimum 10 times the outside diameter of the fiber optics cable or of the largest cable in the harness.

5.2.4 Test

5.2.4.1 Installation Check - As soon as possible following installation, each cable shall be tested for continuity (Paragraph 6.4.1), individual cable loss (Paragraph 6.4.2), or system cable loss (Paragraph 6.4.2). Refer to Table G-1 for acceptance criteria.

5.2.4.2 System Check - An end to end system check of the total cable losses per Paragraph 6.4.2, shall be made immediately after all cable segments are joined together. Refer to Table G-1 for acceptance criteria.

TABLE G-1. ACCEPTANCE CRITERIA

Test	Acceptance Criteria
Continuity (Paragraph 6.4.1)	— Bright Light is Visible at End of Cable. If in Doubt, Perform Paragraph 6.4.2 Test.
Cable Loss (Paragraph 6.4.2)	— 2 dB Maximum for a Single Cable — Allow an Additional 3 dB for Each Cable Added in Series, That Is, 2 Cables in Series - 5 dB Maximum, 3 Cables in Series - 8 dB Maximum, Etc.

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6.0 PROCEDURES

6.1 GENERAL

6.1.1 When installing harnesses in an aircraft, conform to the standard procedure for installation of wire harnesses and the requirements of this specification.

6.2 CLEANING

6.2.1 Prior to mating, inspect the polished fiber ends for damage, contamination, or debris. The socket contact should be closely inspected for debris. If debris is visible or if losses are extensive, use pressurized clean gas (Paragraph 3.1) to dislodge the debris. If pressurized clean gas is not available or is not successful, a metal probe may be used. Care must be taken not to damage the contact parts or to scratch the polished fiber end. When the debris has been cleared, spray the tip of the fiber optics contacts with Freon TF (Paragraph 3.2), and dry them with an optical wiping tissue (Paragraph 3.4) or Q-Tip. If Freon TF is not available, the fiber ends may be cleaned by dipping into or brushing them with alcohol (Paragraph 3.3). Allow the contacts to air dry for 30 seconds or more.

6.3 COUPLING CONNECTORS

6.3.1 Position the plug of the connector so that the keyway of the plug and receptacle line up. Slide the coupling nut onto the receptacle shell and turn the nut until it is fully engaged. When coupling MIL-C-38999 Series III connectors, extra caution should be taken to ensure that the contacts of the connector are

engaged to a definite stop. When the receptacle is positioned so there is a clear view of the red line, tighten the coupling nut until the red line is no longer visible and the coupling nut will no longer turn. If the red line cannot be clearly viewed, tighten the coupling nut as far as possible by hand. Finish tightening the nut with an appropriate spanner wrench or a leather or fabric strap wrench until the connector bottoms out and the coupling nut will no longer turn.

6.4 TEST PROCEDURES

6.4.1 Continuity Check - Using a 2 "D"-cell flashlight (Paragraph 4.1.1) as a source at either end of test cable, ensure that light is visible at the other cable end.

6.4.2 Cable Loss Measurement - Measure cable loss using the OATS (Paragraph 4.1.2) test set as follows:

6.4.2.1 Connect one pigtail cable to the RECEIVE port of the OATS.

6.4.2.2 Connect another pigtail cable to the TRANSMIT port of the OATS.

6.4.2.3 Connect the two cables together.

6.4.2.4 Adjust the ATTEN-O-ADJ knob for 0.00 on the display.

6.4.2.5 Insert the individual cable or cable system to be tested between the two cables.

6.4.2.6 Read the loss in dB in the display window.

6.5 CONNECTOR PROTECTION

6.5.1 When the connectors are unmated, cover the contacts with a plastic dust cap (Paragraph 3.5), a polyethylene bag (Paragraph 3.6) or other device to prevent damage or contamination.

7.0 QUALITY ASSURANCE PROVISIONS

7.1 Surveillance shall be maintained to ensure adherence to Section 5 requirements.

7.2 PROCESS CONTROL

7.2.1 Surveillance shall be maintained to ensure adherence to Section 6 procedures and restrictions.

7.3 ACCEPTANCE CONTROL

7.3.1 Verify that all connections are tight and that all cabling is installed in a neat, orderly manner.

7.3.2 Verify that all hardware (including unused) is tight and that proper hardware has been used.

7.3.3 Measure the loss of each installed cable per Paragraph 6.4. Reject all cables which exceed the allowable losses in Table G-1. Use an OTDR (Paragraph 4.1.3) to locate faults in the cable.

8.0 SAFETY

8.1 GENERAL PRECAUTIONS

8.1.1 First Aid - In event of eye or skin contamination by solvents:

8.1.1.1 Flush the exposed area with large amounts of water.

8.1.1.2 Remove contaminated clothing.

8.1.1.3 Secure first aid immediately.

8.1.2 Toxicology - Avoid prolonged breathing of solvent vapors. If this is impossible, wear a respirator. Respirators used must be approved by the Safety and Medical Department.

8.1.3 Fire Hazard - Do not use solvents in the vicinity of smoking, sparks, or open flames. Flammable solvents are extremely easy to ignite and fires may occur with explosive violence. After using flammable solvents, be certain that no traces linger on clothes or person before leaving a no-smoking area.

8.1.4 Handling and Storage

8.1.4.1 Wear safety glasses (or goggles) and rubber gloves while working with solvents.

8.1.4.2 Do not smoke while working with flammable solvents or while in a no-smoking area.

8.1.4.3 Bare filament heaters or other sources of ignition, including metal objects on shoes, are prohibited in flammable solvent areas. Electrical equipment, including flashlights, shall be explosion proof. Avoid any action which may create sparks, including dragging of steel drums, metal work stands or similar objects, across a concrete floor.

8.1.4.4 Electrically ground any part to be cleaned with a cloth wetted with flammable solvent if the area to be cleaned exceeds one square foot.

8.1.4.5 Isolate flammable solvent storage areas from areas of fire hazard. Electrically ground all equipment in the storage area. Electrically bond dispensing and receiving containers to each other while transferring flammable solvents between the containers.

8.1.4.6 Store and handle solvents in properly labelled safety containers. Keep all containers closed while not in use.

8.1.4.7 Store solvents in cool, well ventilated areas.

8.1.4.8 Do not use solvents in confined areas unless specifically authorized. Ensure that adequate ventilation is provided; the fumes are generally toxic, flammable and explosive.

8.1.4.9 Limit the quantity of flammable solvents in working areas to a one-day supply.

8.1.4.10 Ensure that parts which have been wetted with solvents are completely dry prior to further processing. Unless specifically authorized, the use of heat producing devices to accelerate drying is prohibited.

8.1.4.11 Dispose of all rags in flammable solvent areas in special containers designated for that purpose.

8.2 SOLVENTS

8.2.1 Freon TF - clear, colorless, nonflammable and moderately toxic.

8.2.2 Isopropyl Alcohol - clear, colorless, moderately flammable and moderately toxic.

8.3 GLASS FIBERS

8.3.1 Broken pieces of glass fiber shall not be permitted to remain loose in the work area.

APPENDIX H

1760-PS3 - SPECIFICATION, INTERCONNECT,
FIBER OPTICS, MAINTENANCE/REPAIR PROCEDURES, AIRCRAFT

SPECIFICATION, INTERCONNECT, FIBER OPTICS, MAINTENANCE/REPAIR PROCEDURES, AIRCRAFT

1.0 APPLICATION

1.1 This specification defines the procedures for the maintenance/repair of fiber optics interconnect in military aircraft.

1.2 This specification is applicable when specified by Engineering.

2.0 APPLICABLE DOCUMENTS

2.1 SPECIFICATIONS

MIL-W-5088 - Wiring, Aerospace Vehicle

1760-PS1 - Specification, Interconnect, Fiber Optics, Fabrication of

1760-PS2 - Specification, Interconnect, Fiber Optics, Installation of

1760-TS1 - Course, Training, Fiber Optics, Specification for

3.0 MATERIALS AND/OR SOLUTIONS

3.1 Solvent, Trichlorotrifluoroethane (Freon TF), pressurized spray container - MIL-C-81302.

3.2 Solvent, alcohol, isopropyl - TT-I-735.

3.3 Tissue, optical wiping - Kodak #154-6027 or equivalent.

3.4 Laboratory clean gas

- Micro Duster Kit #TX600 or equivalent
- Micro Duster Refill #TX104 or equivalent

3.5 Caps, dust, plastic - MS90376 various sizes.

3.6 Bags, polyethylene, various sizes.

3.7 Insulation sleeving, heat shrinkable, Polyolefin - M23053/5.

3.8 Tape, pressure sensitive adhesive (PSAT), Teflon, bondable - MIL-T-23594 Type II.

3.9 Tape, lacing or tying - MIL-T-43435.

4. EQUIPMENT AND FACILITIES

4.1 PROCESS EQUIPMENT

4.1.1 Cleaning tank, ultrasonic - Ultromet #75-1970-115-A8 or equivalent.

4.1.2 Insertion/extraction tool, metal, M81969/14-03.

4.1.3 Insertion/extraction tool, plastic, MS27509A16, MS27509R16.

4.1.4 Heat gun, 300°F-500°F ±10° - Master Appliance #HG-301.

4.2 QUALITY ASSURANCE EQUIPMENT

4.2.1 Flashlight, 2 cell, "D" battery size.

4.2.2 Optical Attenuation Test Set (OATS)

- UDT #S550 -- United Detector Technology, Culver City, CA 90230
- Wilcom #T312B -- Wilcom Products Inc., Laconia, NH 03246

4.2.3 Optical Time Domain Reflectometer (OTDR), Suitable for cables less than 30 feet in length -- Optixx #401 or equivalent.

5. REQUIREMENTS

5.1 The requirements of MIL-W-5088 shall be followed except where procedures unique to fiber optics interconnect are specified.

5.2 CONNECTORS

5.2.1 Contact Assembly - Contacts shall be terminated per 1760-PS1.

5.2.2 Contact Insertion & Extraction - All contacts shall be inserted or extracted using plastic or metal tools approved for the connector.

5.2.3 Cleaning - Prior to mating connectors, make certain that the connectors are undamaged, free from dirt, chips, and foreign matter. Immediately prior to mating, the fiber end shall be solvent cleaned and dried per Paragraph 6.1. If the connectors have been unmated only momentarily and maintained clean, the solvent cleaning may be omitted.

5.2.4 Mating - Threaded connectors shall be finger tightened until the red line is no longer visible.

5.2.5 Unmated Connector & Contacts - Unmated connectors & contacts shall be protected from damage or contamination per Paragraph 6.4.

5.2.6 Open Circuit Contacts - Contacts which are determined to have an open circuit shall be cut off and the cable shall be reterminated.

5.3 POLISHED FIBER ENDS

5.3.1 The fiber shall be centered in the contact end, the surface flat, with a minimum of scratches and chips, and exhibiting adhesion to the contact. The fiber shall not protrude from the face of the contact.

5.3.2 Polishing of fiber ends shall be done only with the contact in the polishing fixture and using the procedures of 1760-PS1.

5.4 CABLES

5.4.1 Install cables per 1760-PS2.

5.4.2 Fiber optics cables shall be installed without kinking, folding over, or crushing during handling or installation.

5.4.3 When it is necessary to bend a cable, the bend radius shall be as large as feasible and shall be a minimum 10 times the outside diameter of the fiber optics cable or of the largest cable in the harness.

5.4.4 The cable shall be spliced only after obtaining Engineering approval, using only specified parts.

5.4.5 Damage to the cable outer jacket and strength member which is not greater than 2 inches in continuous length and does not extend more than 90° around the circumference of the cable shall be repaired per Paragraph 6.5. If the cable is damaged more extensively, cut out the damaged area and splice the cable per Paragraph 5.4.4.

5.5 TESTING

5.5.1 The maximum allowable loss for a cable shall be 2dB, plus 3dB for each additional cable connected in series. For example: 1 cable, 2dB; 2 cables, 5dB; 3 cables, 7dB; etc. Measurements shall be made per Paragraph 6.5.2.

5.5.2 For a preliminary circuit evaluation, the continuity check defined in Paragraph 6.5.1 may be performed.

5.6 PERSONNEL

5.6.1 Personnel using these procedures shall have completed the 1760-TS1 training program.

6.0 PROCEDURES

6.1 Cleaning

6.1.1 Inspect for any debris which may have been trapped, especially in the socket contact containing the alignment sleeve. If debris is visible or if losses are excessive, use pressurized clean gas (Paragraph 3.4) to dislodge the debris. If pressurized clean gas is not available or is not successful, a metal probe may be used. Care must be taken not to damage any contact parts or scratch the polished fiber end.

6.1.2 The polished fiber ends shall be cleaned by any of the following methods:

6.1.2.1 Dipping the contact end into an ultrasonic cleaning tank (Paragraph 4.1.1) of Freon TF (Paragraph 3.1) for a minimum of 10 seconds.

6.1.2.2 Spraying the fiber end of the contact with Freon TF (Paragraph 3.1).

6.1.2.3 Dipping into or brushing the fiber end of the contact with alcohol (Paragraph 3.2).

6.1.3 In all of the cleaning methods, the polished fiber end shall be allowed to air dry a minimum of 30 seconds or shall be immediately wiped with an optical wiping tissue (Paragraph 3.3).

6.2 <u>CONTACT INSERTION AND EXTRACTION</u>

6.2.1 Insert contacts into and extract contacts from connectors using the same tools provided for electrical contacts (Paragraphs 4.1.2 and 4.1.3). The contact must be fully inserted and the contact locking system must be engaged. Apply tension to the cable to verify contact locking.

6.3 <u>CONNECTOR COUPLING PROCEDURE</u>

When coupling MIL-C-38999 Series III connectors, extra caution should be taken to ensure that the contacts are engaged to a definite stop. When the receptacle is positioned so there is a clear view of the red line, tighten the coupling nut until the red line is no longer visible and the coupling nut will no longer turn. If the red line cannot be clearly viewed, tighten the coupling nut as far as possible by hand. Finish tightening the nut with an appropriate spanner wrench, or a leather or fabric strap wrench until the connector bottoms out and the coupling nut will no longer turn.

6.4 <u>CONNECTOR CONTACT PROTECTION</u>

6.4.1 Polished fiber ends shall be protected before and after installation into the connectors by any of the following methods:

6.4.1.1 Plastic dust cap (Paragraph 3.5)

6.4.1.2 Polyethylene bag (Paragraph 3.6)

6.4.13 Other device which provides protection from damage and contamination.

6.5 <u>CABLE REPAIR</u>

6.5.1 Cables which exhibit damage to the outer jacket and strength member shall be repaired as follows:

6.5.1.1 Where the end of the cable is accessible, slide a length of shrink sleeving (Paragraph 3.7) over the damaged area. The shrink sleeve material shall be long enough to extend 1 inch past each end of the damaged area. Shrink the sleeving in place using a heat gun (Paragraph 4.1.3)

6.5.1.2 Cover the shrink sleeving with a convoluted wrap of tape (Paragraph 3.8). The tape shall overlap itself by 50%. Use lacing tape (Paragraph 3.9) to secure the free end of the wrapping tape.

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Figure J-9. Fiber Cleaning Using Freon TF Spray

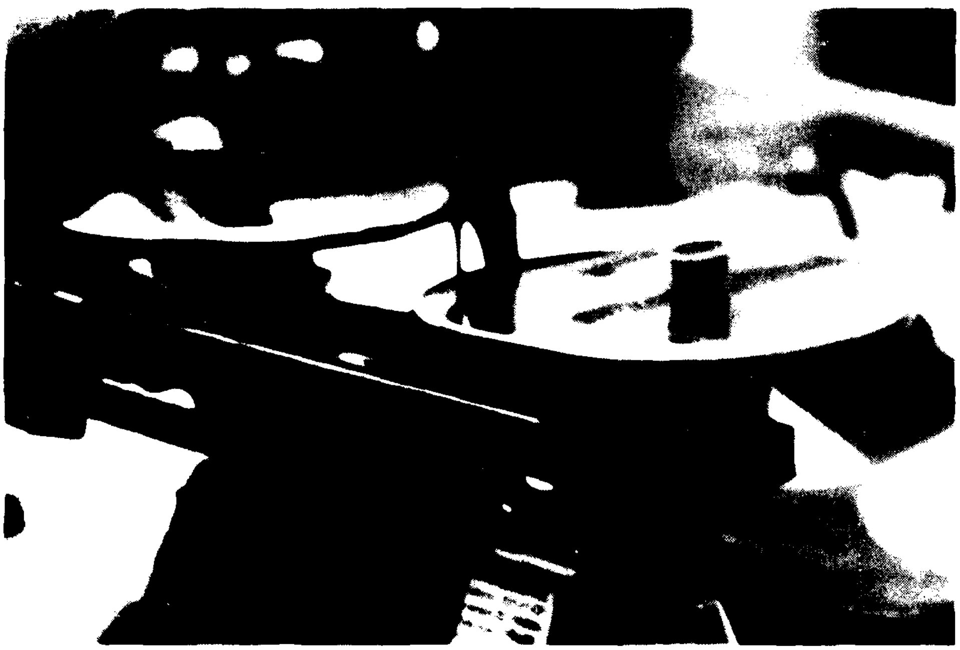

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Figure J-10. Epoxy Measurement

GP43-0551-10

Figure J-7. Strength Member Trim

GP43-0551-11

Figure J-8. Buffer Removal

GP43-0551-8

Figure J-5. Strip Measurement

GP43-0551-9

Figure J-6. Strength Member Comb Out

5.2.6 Mating - Polished fiber ends shall be cleaned per Paragraph 6.4 immediately prior to mating with other components. EXCEPTION: In a clean room, the polished ends may be left unprotected for up to one hour prior to mating, without recleaning.

5.3 HARNESS FABRICATION

5.3.1 General - All braiding and shielding procedures will conform to present methods used on standard electrical interconnect systems.

5.3.2 Harness Length - The length tolerance in completed fiber optics harnesses shall be plus +0.5, -0.0 inch.

5.3.3 Branches - The branch break-out tolerance shall be ± 0.50 inch from the position shown on the harness board.

5.3.4 Splices - Fiber optics cable shall be spliced only when authorized by Engineering. Replace the cable when jacket damage exceeds superficial nicks or scuffing or when the losses defined in Paragraph 5.2.4 are exceeded.

5.3.5 Radius of bend - Wiring bend radii shall comply with the requirements of MIL-W-5088, with the exception that for an individual fiber optics cable, the minimum bend radius allowable is ten times the outside diameter of the cable.

5.3.6 Unbraided harness - Plastic cable straps per MIL-W-5088 shall be used as secondary support to form the harness and to secure breakouts. The straps shall be spaced at intervals not greater than 12 inches.

6.0 PROCEDURES

6.1 CABLE TERMINATION

6.1.1 Trim and prepare the cable to the dimensions shown in Figures J-5 through J-8 with the tools listed in Table J-2.

6.1.2 Cleaning - Clean the portions of the cable and the connector parts to be epoxied by dipping them in the ultrasonic tank (Paragraph 4.1.1) of liquid Freon TF (Paragraph 3.2.1). If not available, use Freon TF spray (Paragraph 3.2.2). Wipe the fiber clean with a tissue or cotton cloth wiper (Paragraph 3.2.4 or 3.2.5), and allow the fiber to dry for 30 seconds or more. See Figure J-9.

6.1.3 Epoxy Mixing

CAUTION: Avoid epoxy contact with skin and eyes. Use in a well ventilated area.

6.1.3.1 Elevated Temperature Cure Epoxy - Mix equal parts by weight of the two part epoxy (Paragraph 3.1.1) in a clean glass, stainless steel, paper, or polyethylene container. See Figure J-10. Stir thoroughly with a clean wood, glass, or stainless steel stirrer. The mixed pot life is 8 hours or longer. Keeping the container closed when the epoxy is not being used will extend its pot life. Discard the material when it starts to gel. Use the Paragraph 3.1.1 epoxy for general production.

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Figure J-4. Outer Jacket Removal

TABLE J-1. TOOLS FOR STRIPPING

Cable Component to Be Removed	Stripping Method
Outer Jacket	Paragraph 4.1.8, 4.1.9, or 4.1.10
Braid	Scissors or Equivalent
Inner Jacket	Paragraph 4.1.11 or 4.1.12
Buffer	Paragraph 4.1.13 or 4.1.14

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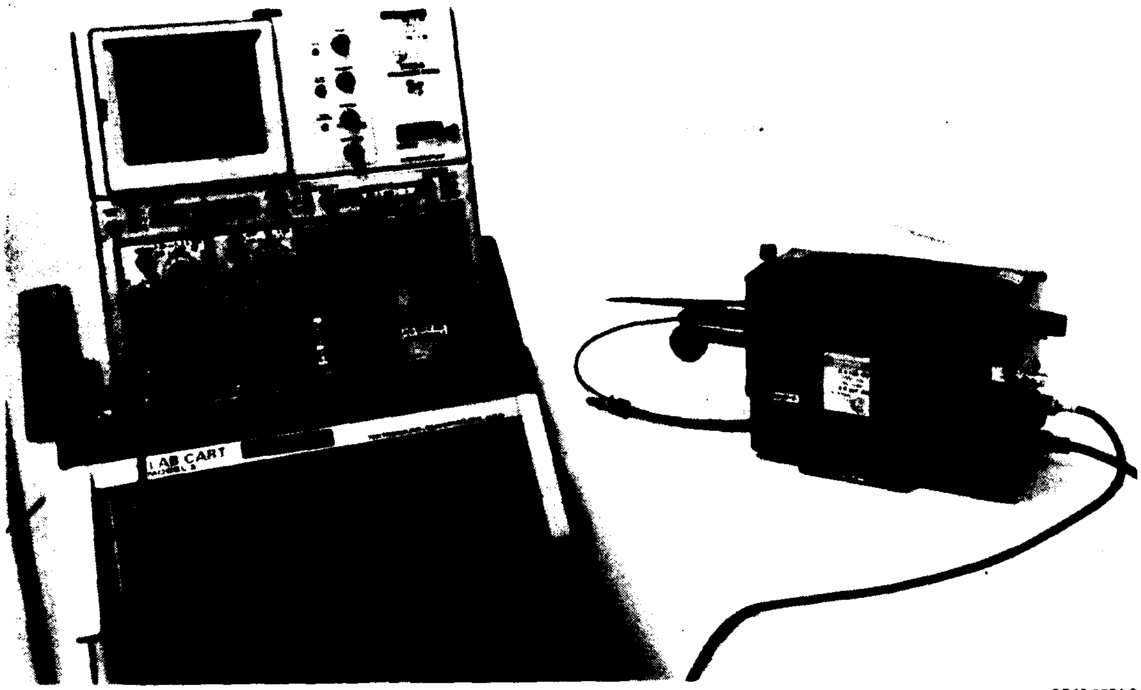

GP43-0551-6

Figure J-3. Optical Time Domain Reflectometer (OTDR)

5.0 REQUIREMENTS

5.1 GENERAL

5.1.1 When a fiber optics cable is routed within a wire harness, the harness shall meet the requirements of MIL-W-5088.

5.2 CABLE TERMINATION

5.2.1 Jacket stripping - The jacket shall be removed to expose the fiber without damaging the fiber. See Figure J-4.

5.2.2 Cleanliness - The jacket, fibers, and contacts which are to be joined with epoxy shall be clean and dry prior to epoxy application.

5.2.3 Fiber End Finish - The fiber shall be centered in the contact, be flat with a minimum of scratches or chips, exhibit proper adhesion to the contact, and shall not protrude from the face of the polishing fixture.

5.2.4 Allowable Losses - The losses in the cable shall be measured per Paragraph 7.2.4. Reject any cable whose losses exceed the value given in Table J-1. A cable with terminations on each end must meet this requirement in both directions.

5.2.5 Polished Fiber Protection - The polished fiber ends shall be protected from damage and/or contamination.

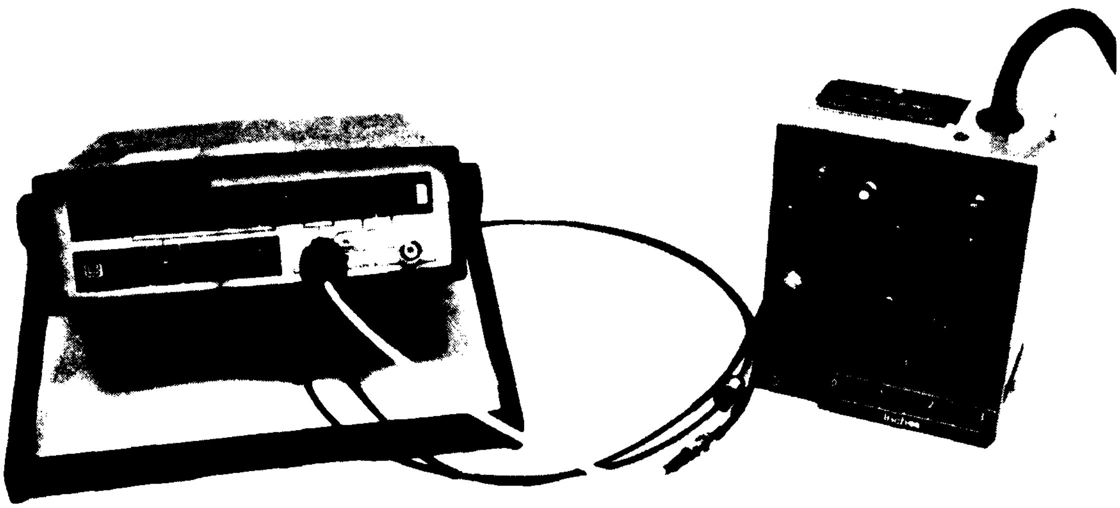

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Figure J-1. Optical Attenuation Test Set (OATS)

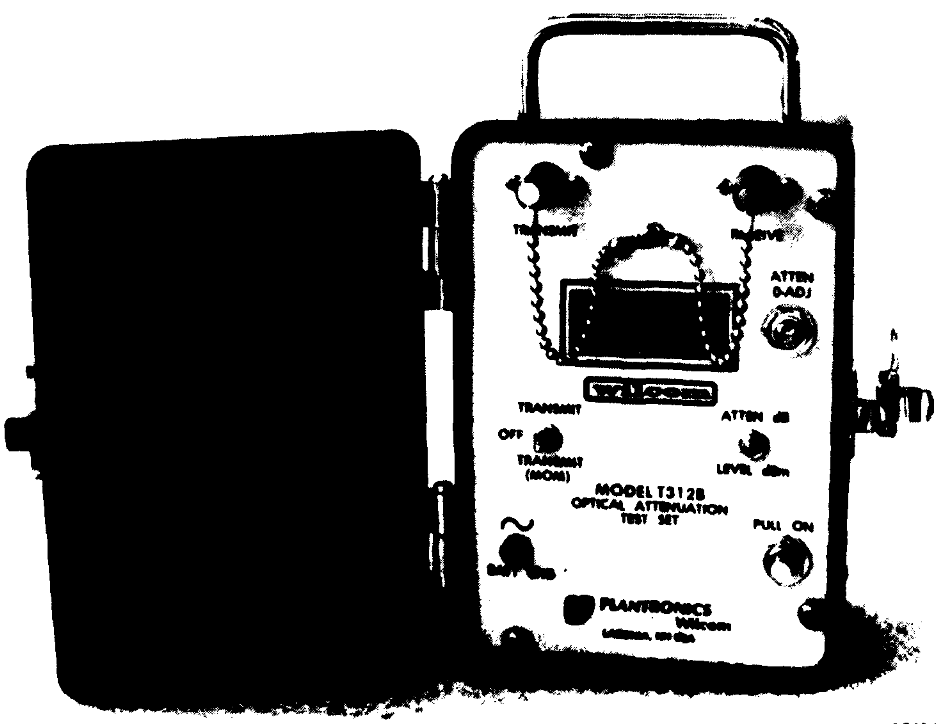

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Figure J-2. Optical Attenuation Test Set (OATS)

4.1.1 Cleaning tank, ultrasonic, Ultromet 75-1970-115-A8 or equivalent

4.1.2 Hypodermic needle, Yale 18 gage, 1-1/2 inches long, Becton-Bickinson Co. (used with 4.1.3)

4.1.3 Syringe, disposable, 5cc, #156-000, Curtin Co.

4.1.4 Oven, air circulating, 150°F-300°F ± 10°

4.1.5 Fixture, polishing

(a) 317-1774-000, ITT Cannon, Santa Ana, CA 92702, for 1760-CS2-1 and 1760-CS3-1.

(b) L36251-321, Amphenol Products, Sidney, NY 13838, for 1760-CS2-2 and 1760-CS3-2.

4.1.6 Heat gun, 300°F-500°F ± 10°--HG 301, Master Appliance, Racine, Wis.

4.1.7 Insertion/removal tool, M81969/14-03

4.1.8 Stripper, blade, 45-176 with L-5559 blade set--Ideal Industries Inc.

4.1.9 Stripper, blade, 45-162 with L-9225 blade--Ideal Industries Inc.

4.1.10 Blade, razor or exacto type

4.1.11 Stripper, blade, 45-176 with L-4994 blade set--Ideal Industries Inc.

4.1.12 Stripper, blade, No-nik, 0.0201 cutting range, royal blue, Clauss Cutlery Co., Fremont, Ohio.

4.1.13 Stripper, blade, Model MS, Micro-Strip 0.008, Utica Tool Co. Inc.

4.1.14 Stripper, blade, No-nik, 0.010 cutting range, light blue, Clauss Cutlery Co., Fremont, Ohio.

4.2 QUALITY ASSURANCE EQUIPMENT

4.2.1 Magnifier, 20-40x

4.2.2 Optical Attenuation Test Set (OATS)

(a) UDT #S550, United Detector Technology, Culver City, CA 90230. See Figure J-1.

(b) Wilcom #T312B, Wilcom Products Inc., Laconia, NH 03246. See Figure J-2.

4.2.3 Optical Time Domain Reflectometer (OTDR), resolution - 40cm, Probe, Pulse Width - 4ns FWHM, Probe, Pulse Return - 1ns, OPTIXX Model 401. See Figure J-3.

SPECIFICATION, INTERCONNECT, FIBER OPTICS, FABRICATION OF (TRAINING)

1.0 APPLICATION

1.1 This specification defines the procedures for the fabrication of a fiber optics interconnect system. It contains only those procedures which are unique to fiber optics. All other standard electrical interconnect procedures will be utilized.

1.2 This specification is applicable when specified on the Engineering drawings and other process specifications or applicable documents.

2.0 APPLICABLE DOCUMENTS

2.1 ISSUES OF DOCUMENTS - The following document, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

MIL-W-5088 Wiring, Aerospace Vehicle.

3.0 MATERIALS AND/OR SOLUTIONS

3.1 END ITEMS MATERIALS

3.1.1 Epoxy, elevated temperature cure, two-part - 1760-MS1.

3.1.2 Epoxy, elevated temperature cure - premeasured 4 gram, 2 pouch kit, 1760-MS1.

3.2 OTHER MATERIALS

3.2.1 Solvent, Freon TF, liquid, MIL-C-81302.

3.2.2 Solvent, Freon TF, pressurized spray container, MIL-C-81302.

3.2.3 Solvent, alcohol, isopropyl, FED TT-I-735.

3.2.4 Tissue, optical wiping - Kodak #154-6027 or equivalent.

3.2.5 Cotton cloth wipers - Cheesecloth, commercial.

3.2.6 Polishing sheets, adhesive backed, Color/Micron -- Blue/40, Yellow/12, Pink/3, Violet/1. Imperial PSA Lapping Film Sheets, 3M Co., Minneapolis, MN.

3.2.7 Caps, dust, plastic, MS90376

3.2.8 Bags, polyethylene, various sizes

4.0 EQUIPMENT AND FACILITIES

4.1 PROCESS EQUIPMENT

APPENDIX J

1760-PS1-TM - SPECIFICATION, INTERCONNECT, FIBER OPTICS, FABRICATION OF (TRAINING)

8.2.2 Isopropyl alcohol - clear, colorless, moderately flammable and moderately toxic.

8.3 GLASS FIBERS

8.3.1 Broken pieces of glass fiber shall not be permitted to remain loose in work areas.

9.0 NOTES

9.1 The time necessary to prepare a single contact termination is about 40 minutes. This is based on 5 minutes to strip the cable and assemble the contact, 30 minutes to cure the epoxy, and 5 minutes for polishing. On an aircraft in service, the elapsed termination time may be longer.

8.1.3 Fire Hazard - Do not use solvents in the vicinity of smoking, sparks, or open flames. Flammable solvents are extremely easy to ignite and fires may occur with explosive violence. After using flammable solvents, be certain that no traces linger on clothes or person before leaving a no-smoking area.

8.1.4 Handling and Storage

8.1.4.1 Wear safety glasses (or goggles) and rubber gloves while working with solvents.

8.1.4.2 Do not smoke while working with flammable solvents or while in a no-smoking area.

8.1.4.3 Bare filament heaters or other sources of ignition, including metal objects on shoes, are prohibited in flammable solvent areas. Electrical equipment, including flashlights, shall be explosion proof. Avoid any action which may create sparks, including dragging of steel drums, metal work stands, or similar objects, across a concrete floor.

8.1.4.4 If a part to be cleaned by a cloth wetted with flammable solvent has an area to be cleaned exceeding one square foot, that part shall be electrically grounded.

8.1.4.5 Isolate flammable solvent storage areas from areas of fire hazard. Electrically ground all equipment in the storage area. Electrically bond dispensing and receiving containers to each other while transferring flammable solvents between the containers.

8.1.4.6 Store and handle solvents in properly labelled safety containers. Keep all containers closed while not in use.

8.1.4.7 Store solvents in cool, well ventilated areas.

8.1.4.8 Do not use solvents in confined areas unless specifically authorized. Ensure that adequate ventilation is provided; fumes are generally toxic, flammable, and explosive.

8.1.4.9 Limit the quantity of flammable solvents in working areas to a one-day supply.

8.1.4.10 Ensure that parts which have been wetted with solvents are completely dry prior to further processing. Unless specifically authorized, the use of heat producing devices to accelerate drying is prohibited.

8.1.4.11 Dispose of all rags from flammable solvent areas in special containers designated for that purpose.

8.2 SOLVENTS

8.2.1 Freon TF - clear colorless, nonflammable and moderately toxic.

TABLE H-1. TROUBLE CORRECTION PROCEDURES

Trouble	Possible Problems	Corrections
No Light (Open)	Open at Connector	
	— Connector Uncoupled	Couple All Connectors in Test Circuit (Paragraph 6.3)
	— Connector Not Fully Coupled	Fully Couple Connector (Paragraph 6.3)
	— Connector Will Not Fully Couple	Replace Connector (Paragraph 6.3)
	— Contact Not Fully Seated in Connector	Extract and Reinsert Contact (Paragraph 6.2)
	Open Cable	
	— Crushed Cable	Replace Interconnect Assembly or Repair Splice (Paragraph 6.4)
	— Cut Cable	Replace Interconnect Assembly or Repair Splice (Paragraph 6.4)
	— Kinked or Folded Over	Replace Interconnect Assembly or Repair Splice (Paragraph 6.4)
Excessive Losses	Connector Not Fully Coupled	Fully Couple Connector (Paragraph 6.3)
	Connector Will Not Fully Couple	Replace Connector (Paragraph 6.3)
	Contamination at Polished Fiber	Clean (Paragraph 6.1)
	Debris at Polished Fiber (More Likely at Socket End)	Remove Debris and Clean (Paragraph 6.1)
	Alignment Sleeve Missing From Socket	Install Alignment Sleeve (1760-PS1)
	Alignment Sleeve Damaged	Replace Alignment Sleeve (1760-PS1)
	Fiber End Damaged (Scratched Cracked, Chipped)	Repolish or Replace Contact (1760-PS1)

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7.2.4 Reject all cables with unauthorized splices or connectors.

7.2.5 Verify proper strain relief at the connector.

8. SAFETY

8.1 GENERAL PRECAUTIONS

8.1.1 First Aid - In event of eye or skin contamination by solvents:

8.1.1.1 Flush the exposed area with large amounts of water.

8.1.1.2 Remove contaminated clothing.

8.1.1.3 Obtain first aid immediately.

8.1.2 Toxicology - Avoid prolonged breathing of solvent vapors. If this is impossible, wear a respirator. Respirators used must be approved by the Safety and Medical Department.

6.5.2 Cables with excessive damage cannot be repaired. The damaged section must be cut out and the cable spliced (Paragraph 5.4.5).

6.6 <u>TEST PROCEDURES</u>

6.6.1 <u>Continuity Check</u> - Using a 2 cell, "D" battery size flashlight (Paragraph 4.2) as a source at either end of the test cable, visually inspect for light to be transmitted to the other end of the cable.

6.6.2 Measure cable loss using the OATS (Paragraph 4.1.1) as a source and a receiver as follows.

6.6.2.1 Connect one jumper cable to the RECEIVE port of the OATS (Paragraph 4.3.6).

6.6.2.2 Connect another jumper cable to the TRANSMIT port of the OATS (Paragraph 4.3.6).

6.6.2.3 Connect the two cables together.

6.6.2.4 Adjust the ATTEN-O-ADJ knob for 0.00 on the display.

6.6.2.5 Insert the cable or cable system to be tested between the two jumper cables.

6.6.2.6 Read the loss in dB in the display window.

6.6.3 If the continuity check (Paragraph 6.5.1) or the OATS (Paragraph 6.5.2) measurement is not acceptable, refer to Table H-1 for correction procedures.

<u>7.0 QUALITY ASSURANCE PROVISIONS</u>

7.1 <u>Process Control</u>

7.1.1 Verify that the polished fibers are protected from damage or contamination.

7.1.2 Verify that the contact termination is performed according to 1760-PS1.

7.1.3 Verify that personnel have been trained per 1760-TS1.

7.2 <u>ACCEPTANCE CONTROL</u>

7.2.1 Visually inspect to verify that the cured epoxy shows proper adhesion between the fiber and the ferrule.

7.2.2 Visually inspect the cable and terminated ends for damage - nicks, scratches, contamination, etc.

7.2.3 Verify that loss measurements do not exceed Paragraph 5.4.1 maximum values.

TABLE J-2. EPOXY CURE SCHEDULE

Minimum Time (hr)	Temperature ±10°F
1/2	300*
2	250

*A heat gun (Paragraph 4.1.7) may be used if the temperature is monitored to ± 25°F. With the nozzle vents open, the temperature should be 300°F about 1-1/2 - 2 inches from the nozzle end.

Caution: Exercise Care That Heat From the Heat Gun Is Not Directed at Heat Sensitive Materials or Parts in Adjacent Areas.

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6.1.3.2 Premeasured 2 Pouch Kit, Elevated Temperature Cure Epoxy - Remove the separator from the premeasured 2 pouch kit (Paragraph 3.1.2). Knead the epoxy while it is still in the packet. Cut off a corner of the packet to dispense the epoxy. The mixed pot life is 8 hours or longer. Discard the material when it starts to gel. Use Paragraph 3.1.2 epoxy where only a few terminations are to be made.

6.1.4 Epoxy Application

6.1.4.1 Install the hypodermic needle (Paragraph 4.1.2) on the syringe (Paragraph 4.1.3). Fill the syringe with epoxy. Hold the syringe with the needle pointed upward so that any air bubbles will rise to the surface. Force air bubbles out of the syringe through the needle. See Figure J-11. Insert the syringe into the rear of the contact as far as possible and slowly fill the contact half full with epoxy. (Take care not to get air bubbles into the contact.) Epoxy should come through the hole at the end of the connector. See Figure J-12.

6.1.4.2 Wrap a strip of Teflon or other non-adhesive material around the strength member to hold it in place. Slide the contact over the stripped cable, rotating the contact until the fiber finds the hole. See Figure J-13. Work the Teflon back as the braid goes into the contact. When all but 0.1 inch of fiber is protruding from the end of contact, the cable is properly seated.

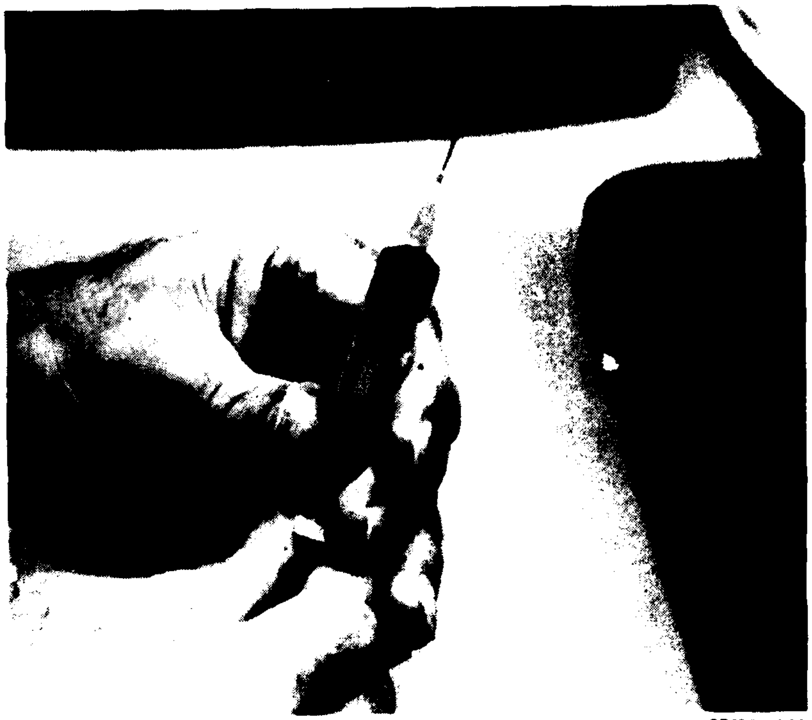

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Figure J-11. Removal of Air From Epoxy-Filled Syringe

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Figure J-12. Fill Contact With Epoxy

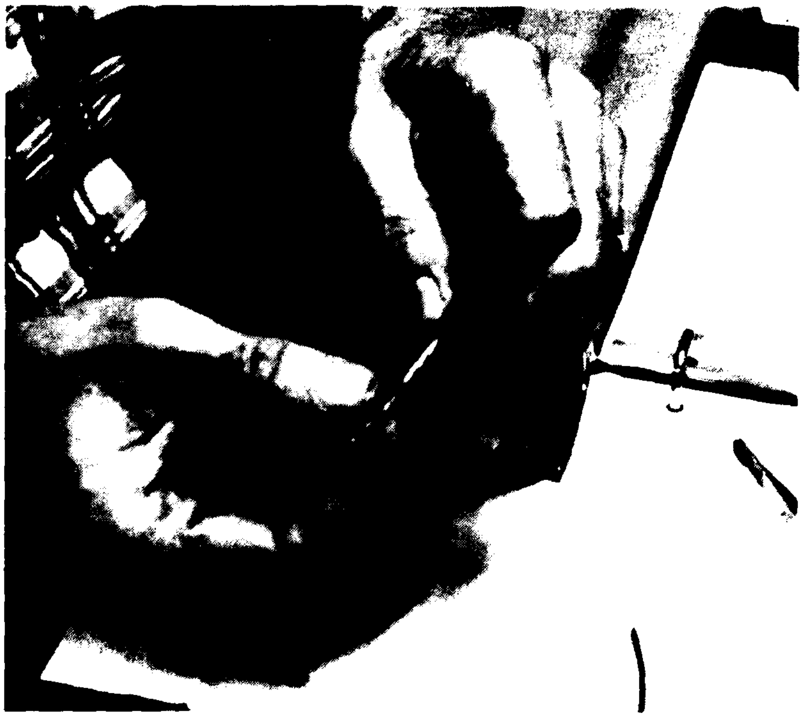

Figure J-13. Cable Insertion

NOTE: Ensure that the strength member is not bunched at the base of the contact.

6.1.4.3 Apply a drop of epoxy at the fiber tip and remove any excess epoxy from the exterior of the contact with a wiper (Paragraph 3.2.5).

6.1.4.4 Cure the termination assembly in a horizontal position in accordance with Table J-3. See Figures J-14, J-15.

6.1.5 <u>Fiber End Finish</u>

6.1.5.1 Carefully cut or break off any excess fiber at the surface of the epoxy bead, leaving 1/16 inch or more to be ground off. For this operation, nail clippers or their equivalent may be used to cut the protruding fiber, or the fiber may be broken off by simply bending the fiber with your fingers.

6.1.5.2 Insert the contact into the polishing fixture (Paragraph 4.1.5) so that the untrimmed fiber will extend beyond the fixture face.

6.1.5.3 Position a blue polishing sheet (Paragraph 3.2.6) on a flat surface and apply clean tap water over area to be utilized. Water is necessary as a lubricant.

TABLE J-3. ACCEPTANCE CRITERIA

Test	Acceptance Criteria
Cable Loss	— 2 dB Maximum for a Single Cable Segment. — Allow an Additional 3 dB for Each Cable Segment Added in Series, That Is, 2 Cables in Series - 5 dB Maximum, 3 Cables in Series - 8 dB Maximum, etc.

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Figure J-14. Oven Cure

Figure J-15. Heat Gun Cure

6.1.5.4 Move the polishing fixture in a long figure eight motion until a thin layer of epoxy just covers the fiber end face. See Figure J-16. Flush the fiber end, polishing fixture, and work area with clean water.

6.1.5.5 Turn the polishing fixture so that the polishing direction is perpendicular to the prior polishing direction. Using yellow polishing sheets, polish the end of the fiber until all scratch marks have been removed. Flush the fiber end, polishing fixture, and work area with clean water.

6.1.5.6 Repeat the steps in Paragraph 6.1.5.5 using the pink polishing sheets.

6.1.5.7 Repeat the steps in Paragraph 6.1.5.5 using the violet polishing sheets. Verify that neither the contact nor the fiber protrude past the fixture by drawing a straight edge across face of the polishing fixture.

6.1.5.8 Wash the tip of the contact using clean water and clean the contact ultrasonically using Freon (Paragraph 3.2.1). If the ultrasonic tank (Paragraph 4.1.1) is not available, use a dip or spray of Freon TF (Paragraph 3.2.2). Dry the contact with heat (Paragraph 4.1.6) or cotton cloth wipers (Paragraph 3.2.5).

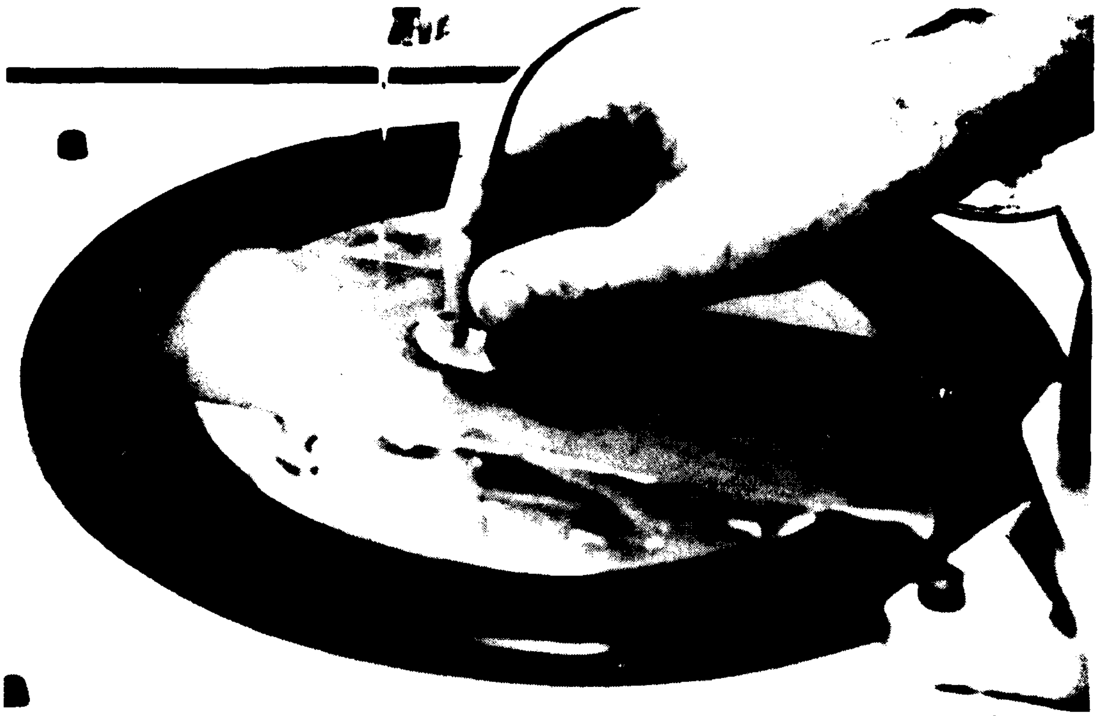

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Figure J-16. Fiber Polish

6.1.5.9 Examine the fiber end for gross imperfections using 40X magnification (Paragraph 4.2.1). Ensure that the optical surface is flat and free of scratches, chips or epoxy smears. See Figure J-17. If necessary, repeat the polishing steps in Paragraphs 6.1.5.5 through 6.1.5.7.

6.1.6 Socket Contract Assembly (Figure J-18)

6.1.6.1 1760-CS3-1 - After polishing is complete, insert the spring into the outer sleeve from the end opposite the shoulder. Then slide these parts over the terminated socket, shoulder end first. The small end of the guide sleeve is then pressed on, captivating the assembly. Lightly pull on the guide sleeve to verify captivation.

6.1.6.2 1760-CS3-2 - The socket contact spring has been factory installed. The long end of the guide sleeve is pressed onto the terminated socket contact until it seats against the socket contact shoulder.

6.2 CONTACT INSERTION INTO CONNECTOR

NOTE: Prior to contact insertion, use a dip or spray of Freon TF (Paragraphs 3.2.1 or 3.2.2) to clean the contact. Dry the contact with heat (Paragraph 4.1.9) or cotton cloth wipers (Paragraph 3.2.8).

Figure J-17. Surface Inspection

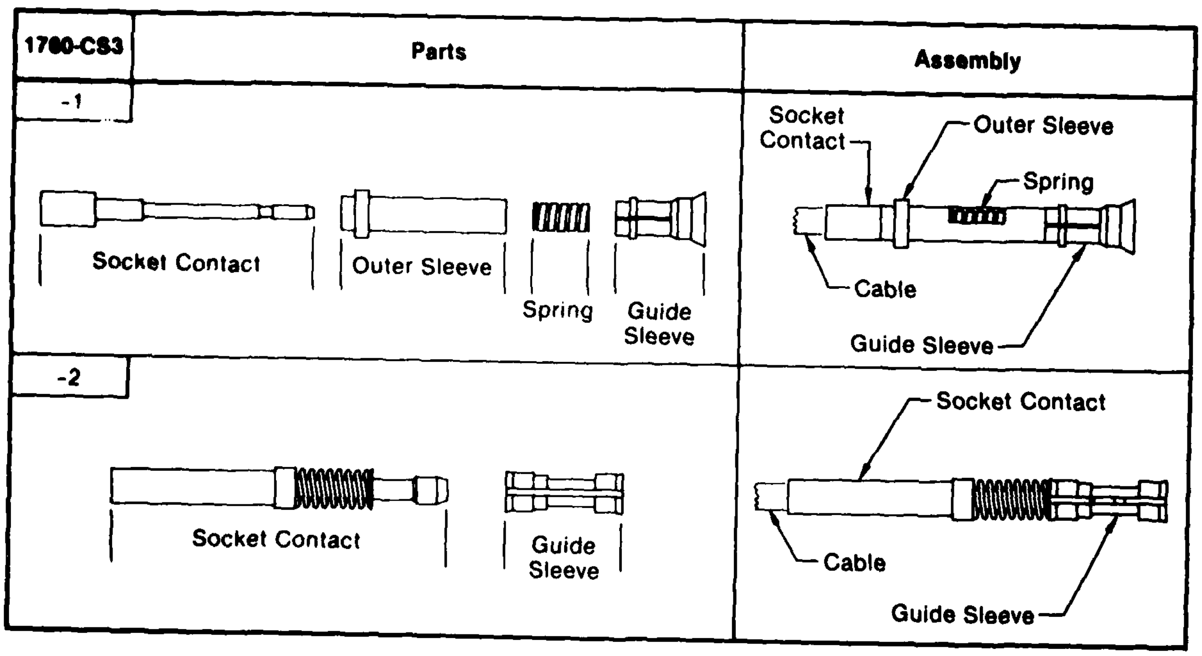

Figure J-18. Socket Connect Assembly

6.2.1 Insert the cable/contact assembly into the connector cavity with the Paragraph 4.1.7 insertion tool. Apply tension to the cable to ensure that the assembly is locked in place.

6.3 HARNESS FABRICATION

6.3.1 Routing - Route fiber optics cables per drawings.

6.3.2 Identification - All identification and marking of cables and harnesses will be accomplished in accordance with the requirements of MIL-W-5088 and this specification.

6.4 CLEANING OF POLISHED FIBER ENDS

6.4.1 Polished fiber ends shall be cleaned by any of the following methods:

6.4.1.1 Dipping the contact end into an ultrasonic cleaning tank (Paragraph 4.1.1) of Freon TF (Paragraph 3.2.1) for a minimum of 10 seconds.

6.4.1.2 Spraying the contact end with Freon TF (Paragraph 3.2.2).

6.4.1.3 Dipping the contact end into alcohol (Paragraph 3.2.3).

6.4.2 In all cleaning methods, the polished fiber end shall be allowed to air dry for 30 seconds or more. If available, wipe the polished fiber end with an optical wiping tissue (Paragraph 3.2.4) immediately after cleaning.

6.5 PROTECTION OF POLISHED FIBER ENDS

6.5.1 The polished fiber ends shall be protected by any of the following methods:

6.5.1.1 Plastic dust cap (Paragraph 3.2.7)

6.5.1.2 Polyethylene bag (Paragraph 3.2.8)

6.5.1.3 Other device which provides protection from damage and/or contamination.

7.0 QUALITY ASSURANCE PROVISIONS

7.1 PROCESS CONTROL - Maintain surveillance as necessary to ensure compliance to the following:

7.1.1 Visually inspect (40X magnification) to ensure that the surface of the contact and fiber is flat and free of scratches or gross imperfections, and that the fiber is not chipped.

7.2 ACCEPTANCE INSPECTION

7.2.1 Visually inspect the cable harness to verify that there are no lump(s) on the harness due to foreign object(s) under the braid.

7.2.2 Visually inspect the termination to verify that the cured epoxy exhibits proper adhesion between the fiber and the contact.

7.2.3 Visually inspect the cable and terminated ends for damage - nicks, scratches, contamination, etc.

7.2.4 All cables with a termination at each end shall be measured with the OATS (Paragraph 4.2.2) to verify that losses do not exceed the values given in Table J-1, in either direction. Reject all cables that fail to meet this requirement. (When there is a larger than a 0.5dB difference in the loss measurements in opposite directions, a fault at one of the connector ends can usually be found.) Use an OTDR (Paragraph 4.2.3) to locate the fault.

7.2.5 Reject all cables with unauthorized splices or connectors.

APPENDIX K

1760-PS2-TM - SPECIFICATION, INTERCONNECT,
FIBER OPTICS, INSTALLATION AIRCRAFT (TRAINING)

SPECIFICATION, INTERCONNECT, FIBER OPTICS, INSTALLATION AIRCRAFT (TRAINING)

1.0 APPLICATION

1.1 This specification defines the procedures for the installation of a fiber optics interconnect system. It contains only those procedures which are unique to fiber optics. All other MIL-W-5088 installation procedures for standard electrical interconnect will be utilized.

1.2 This specification is applicable when specified on the Engineering drawings and other process specifications or applicable documents.

2.0 APPLICABLE DOCUMENTS

2.1 Issues of documents and the following documents, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

(a) MIL-W-5088 Wiring, Aerospace Vehicle

(b) MIL-C-38999 Connector, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded and Breech Coupling), Environmental Resistant, Removable Crimp and Hermetic Solder Contacts, General Specification for

3.0 MATERIALS AND/OR SOLUTIONS

3.1 Laboratory Clean Gas

(a) Micro Duster Kit #TX600 (214-31369)

(b) Micro Duster Refill #TW104 (200-57410)
Texwipe Company, Upper Saddle River, N.J.

3.2 Solvent, Freon TF, pressurized spray container, MS-180 or equivalent
Miller-Stephenson, Morton Grove, IL 60053

3.3 Solvent, alcohol, isopropyl, TT-I-735

3.4 Tissue, optical wiping - Kodak #154-6027 or equivalent

3.5 Caps, dust, plastic, MS90376, various sizes

3.6 Bags, polyethylene, various sizes

4.0 EQUIPMENT AND FACILITIES

4.1 QUALITY ASSURANCE EQUIPMENT

4.1.1 Flashlight, 2 cell, "D" battery size

4.1.2 Optical Attenuation Test Set (OATS)

(a) UDT #S550, United Detector Technology, Culver City, CA 90230. See Figure K-1.

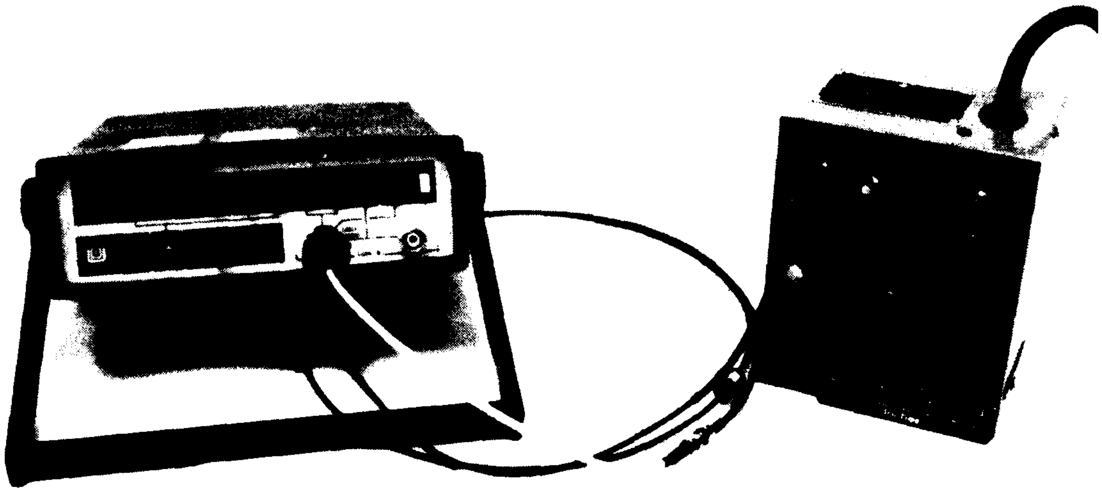

Figure K-1. Optical Attenuation Test Set (OATS)

(b) Wilcom #T312B, Wilcom Products Inc., Laconia, NH 03246. See Figure K-2.

4.1.3 Optical Time Domain Reflectometer (OTDR), suitable for cables less than 30 feet in length, Optixx Model 401, or equivalent. See Figure K-3.

5.0 REQUIREMENTS

5.1 PROCESSING REQUIREMENTS

5.1.1 Fiber optics cables shall not be kinked, folded or crushed during handling or installation. Over-stressing of a copper cable will cause degradation; overstressing of a fiber optics cable will result in complete failure.

5.1.2 Cables and harnesses shall be installed in a neat and orderly manner.

5.1.3 Connectors

5.1.3.1 Cleaning - Prior to mating connectors, ensure that the connectors are undamaged, free from dirt, chips, and foreign matter. Immediately prior to mating, the fiber end shall be solvent cleaned and dried per Paragraph 6.2. If the connectors have been unmated only momentarily and have been kept clean, the solvent cleaning may be omitted.

5.1.3.2 Protection - Unmated connectors shall be protected from damage or contamination.

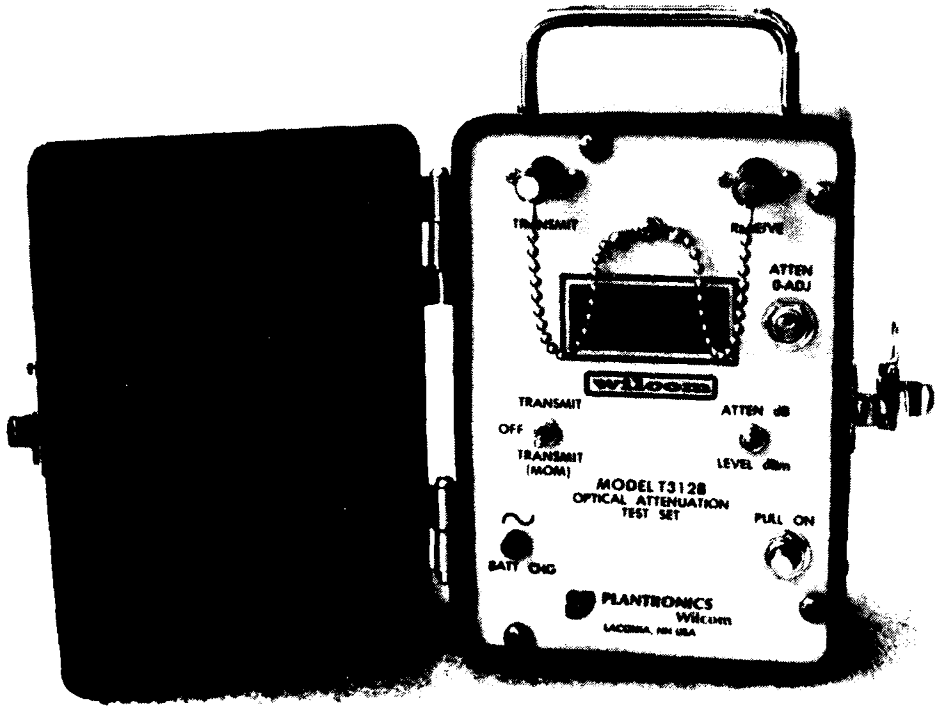

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Figure K-2. Optical Attenuation Test Set (OATS)

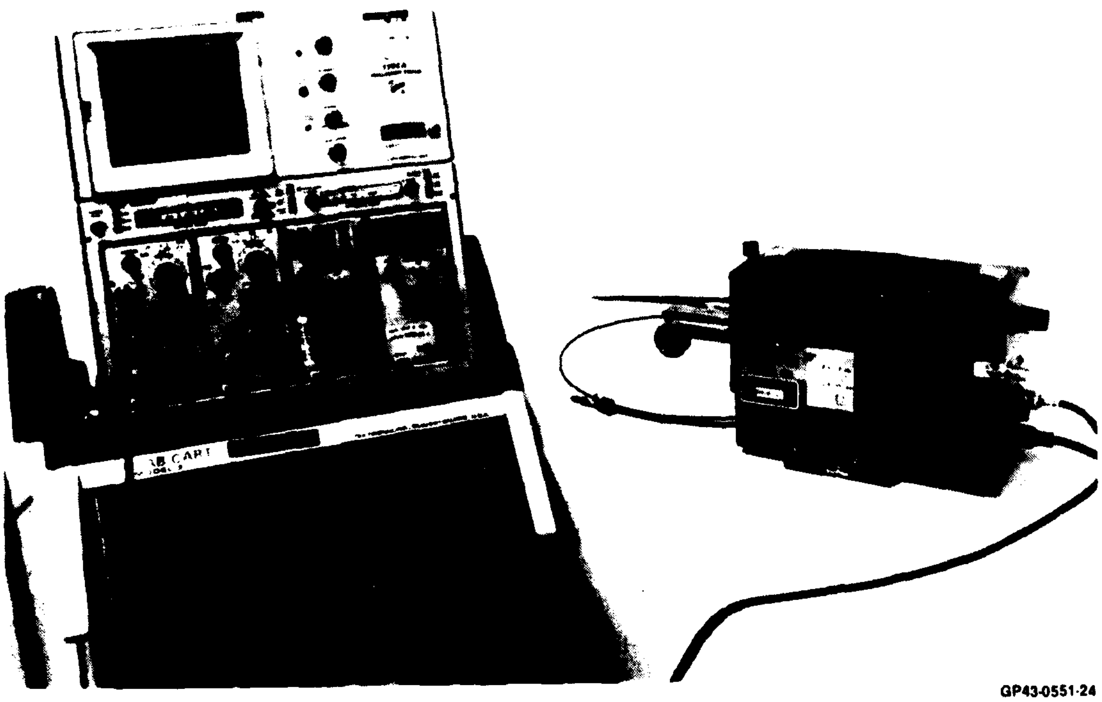

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Figure K-3. Optical Time Domain Reflectometer (OTDR)

5.2 END ITEM REQUIREMENTS

5.2.1 Harnesses - When a fiber optics cable is routed within a wire harness, the harness shall meet the requirements of MIL-W-5088 and other specifications.

5.2.2 Cable Slack - In addition to drip loop requirements, minimum slack shall be left in cables to meet the following requirements:

5.2.2.1 Provide ease of maintenance.

5.2.2.2 Prevent mechanical strain on the cables, cable junctions and cable supports.

5.2.2.3 Provide free movement of shock and vibration mounted equipment.

5.2.2.4 Provide servicing of cockpit console control panels without disturbing any other control panels.

5.2.2.5 Allow a minimum of 1-1/2 inches slack for connector replacement. This slack shall be between the connector and the second wiring support clamp. That is, with the connector unmated and the first clamp loosened, the cable will permit the front end of the connector shell to extend 1-1/2 inches beyond the point normally required to properly mate the connector. Routing shall accomodate slack cable without cable fold back.

5.2.3 Cable Bend Radius - When it is necessary to bend a cable or harness, the bend radius shall be as large as feasible and shall be a minimum 10 times the outside diameter of the fiber optics cable or of the largest cable in the harness.

5.2.4 Test

5.2.4.1 Installation Check - As soon as possible following installation, each cable shall be tested for continuity (Paragraph 6.4.1), individual cable loss (Paragraph 6.4.2) or system cable loss (Paragraph 6.4.2). Refer to Table K-1 for acceptance criteria.

TABLE K-1. ACCEPTANCE CRITERIA

Test	Acceptance Criteria
Continuity (Paragraph 6.4.1)	— Bright Light Is Visible at End of Cable. If in Doubt, Perform Paragraph 6.4.2 Test.
Cable Loss (Paragraph 6.4.2)	— 2 dB Maximum for a Single Cable. — Allow an Additional 3 dB for Each Cable Added in Series, i.e. 2 Cables in Series - 5 dB Maximum, 3 Cables in Series - 8 dB Maximum, etc.

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APPENDIX M

1760-TS1 - COURSE, TRAINING, FIBER OPTICS, SPECIFICATION FOR

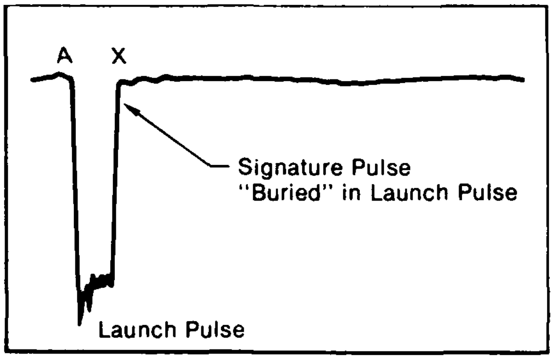

Figure L-14. OTDR Connected to A End

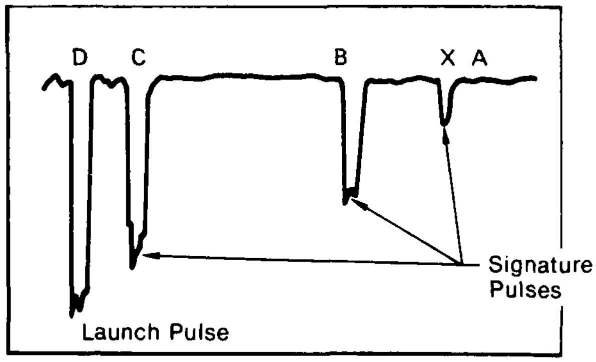

Figure L-15. OTDR Connected to D End

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The above examples should provide enough information to successfully isolate most fiber optics cable malfunctions to the cable break location or connector.

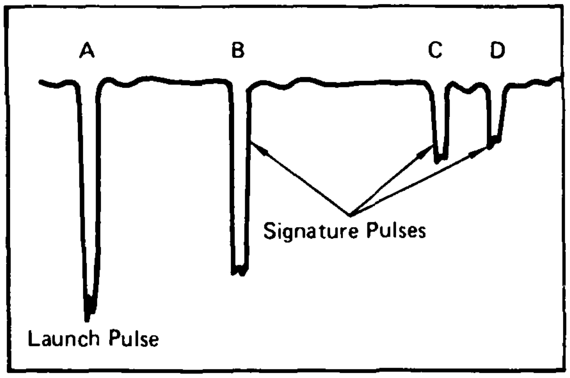

Figure L-10. OTDR Connected to A End

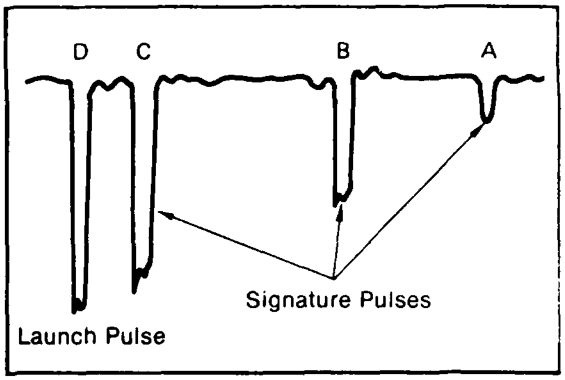

Figure L-11. OTDR Connected to D End

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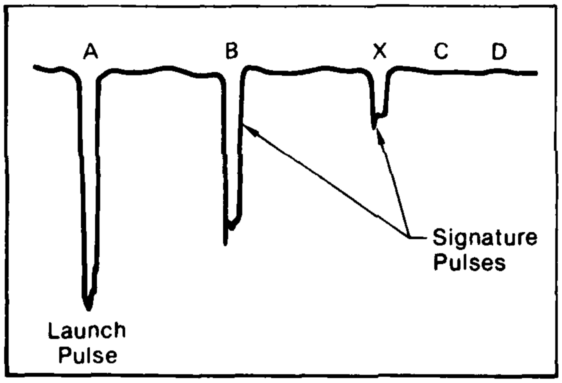

Figure L-12. OTDR Connected to A End

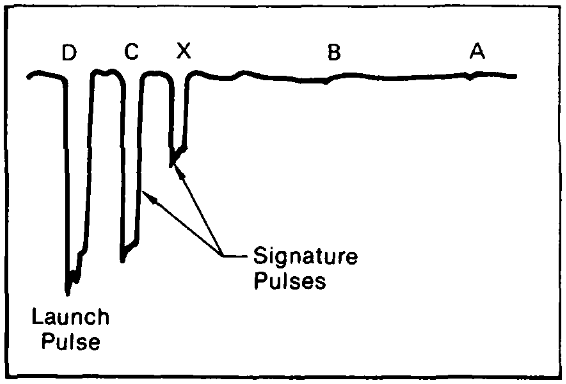

Figure L-13. OTDR Connected to D End

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Figures L-14 and L-15 illustrate a break near end A of the cable. The signature pulse from the break is not completely buried in the launch pulse (Figure L-14), so the break is not at the connector and is likely to be within two meters of end A. Since the leading edge of the pulse cannot be seen, it is not possible to estimate the location of the break from this trace. However, by connecting the OTDR to the opposite cable end (Figure L-15), a near normal signature pulse display is observed except that the final pulse is closer to the B connection than expected from the known length of the BA segment. An estimate of the distance of the break at X from the B connection can be made using Figure L-9. Further, by wetting end A, no change in the signature pulse amplitude of the final pulse will be noted if there is indeed a break in the cable.

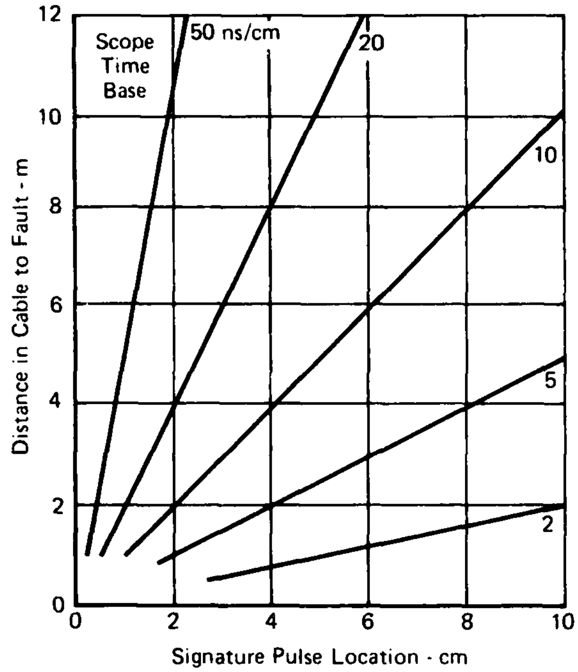

Figure L-9. Conversion of Scope Trace to Cable Fault Location

Typical displays for a normal three segment cable are shown in Figures L-10 and L-11. The OTDR is connected to (arbitrarily chosen) end A. There are a total of four pulses displayed: the launch pulse and three signature pulses from the two in-line connections and the cable end. The distances between two given pulses will be equal regardless of the end to which the OTDR is connected. So, in Figures L-10 and L-11, the distance between the C and D signature pulses is the same whether or not D corresponds to the near end or far end of the cable. Each pulse is successively lower in amplitude since there is less light available for reflection at each successive interface. The limit to the number of segments which can be connected together and still yield a signature pulse is determined primarily by the loss at the connections.

Figure L-12 illustrates the scope display for the same three-segment cable which has a break in the middle segment (BC). As a result there will be no signature pulses at C and D. The amplitude of the signature pulse from the break is a function of how clean the break is; a low amplitude pulse signifies an irregular break. When the OTDR is connected to the opposite end of the cable, Figure L-13, the A and B signature pulses are now missing and the signature pulse from the break is close to the C signature pulse as expected. The location of the break can be calculated using Figures L-12 and L-13 in two ways: (1) the distance from the C connection and (2) the distance from the B connection.

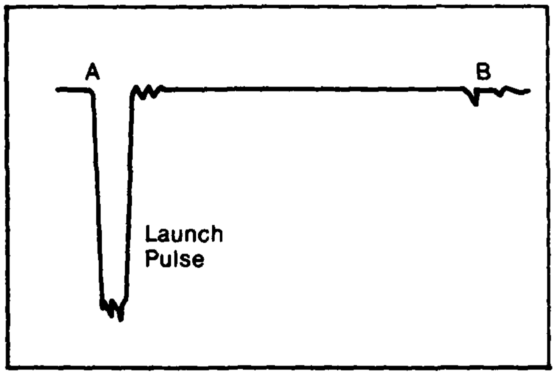

Figure L-7. Break at End A of Cable

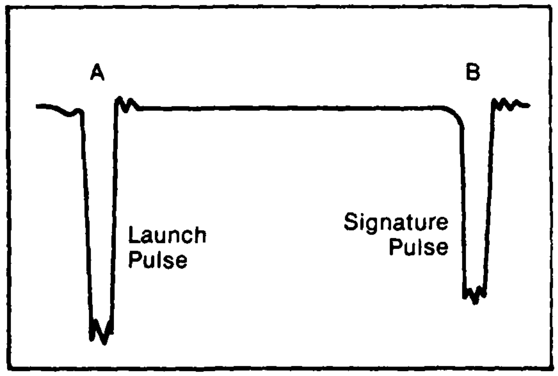

Figure L-8. Break at End B of Cable

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The two cable ends can be reversed and the process repeated for additional confidence. For example, an OTDR signature such as Figure L-7, will change to one like Figure L-8 when ends A and B are exchanged.

After verification of a fiber break in the vicinity of a connector, it is often possible to find the exact location by cautious manipulation of the cable. The OTDR is connected to the end with the suspected break. By applying slight tension to the cable and then wiggling the cable, the offset fibers will often be aligned long enough for a signature pulse to be returned from the opposite end of the cable segment. Therefore, a signature pulse corresponding to the cable end will be seen flashing on the oscilloscope, verifying the existence of a fiber break where the cable is being handled.

The wave forms shown in Figures L-5 through L-8 are typical for cable segments shorter than 20 meters. The launch pulse is 10-20 nsec wide for high performance OTDRs. With the oscilloscope time base set at 20 nsec/cm, a signature pulse 5 cm after the launch pulse corresponds to a 10 meter long cable segment. Figure L-9 is a plot for various oscilloscope settings and can be used to find the distance to a break or cable end from the oscilloscope display.

It has been shown that isolation of a fiber optics cable break to within a short distance of either end is possible using an OTDR, some elementary logic, and by exploiting the properties of optical terminations. These results can be extended to multiple segment cables by merely extending the technique outlined above.

6.3.2 <u>Multiple-Segment Cables</u> - The same principles for troubleshooting one segment fiber optics cables are now applied to multiple-segment cables. It is important to know the number of segments and their lengths so the oscilloscope time base can be set. Any jumper cables used to connect the OTDR to the system under test must also be included in the segment count.

If the broken fiber ends are offset, there will be virtually zero transmission through the cable. This kind of break is the most likely with single fiber cables, and will be indicated by a high loss reading, typically 25 dB or more on most optical attenuation test sets. In this case, it is possible to identify the location of the break with the OTDR even if the break is at the connector.

This method yields the highest confidence if both ends of the cable segment are accessible and the length of the segment is known to within a few tenths of a meter. If a fiber break is more than some critical distance from either end of the cable segment, it will be displayed on the oscilloscope as a normal discontinuity, as Figure L-6 illustrates, and its location can be determined. The critical distance depends on the OTDR used since it is a function of the launch pulse width. For OTDRs such as the Optixx Model 401, the critical distance is about one meter. If the fiber break is "clean," the reflected light pulse will be nearly as strong as it would be from a properly terminated end, and the signature pulse will have nearly the same amplitude in both the normal and the broken cable. If the fiber is shattered, there will be a smaller signature pulse. Finally, with offset broken fiber ends, there will be no signfiicant signature pulse from the end of the cable segment because there is no light in the broken portion of the cable.

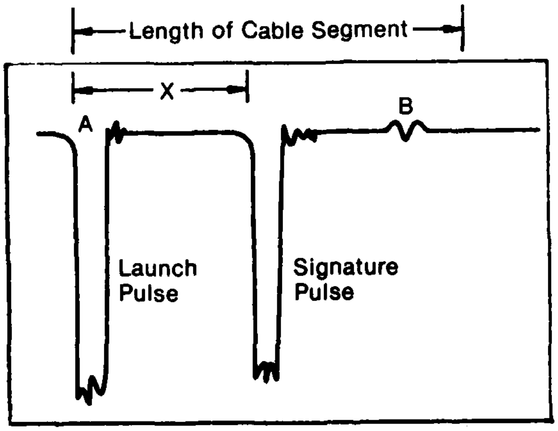

Figure L-6. Break in Middle of Cable

The most common fiber optics cable problem will be a broken fiber in or near a connector. Isolation to the correct cable end is achieved in the following manner. Assume the OTDR is connected to end A. If the offset break is within the critical distance of end A, the reflection from the break will be "buried" in the launch pulse and there will be no signature pulse from end B as shown in Figure L-7. If the offset break is within the critical distance of end B, the signature pulse from the break will appear on the oscilloscope at the same location as the signature pulse from an unbroken cable of the same length, as shown in Figure L-8, since the break is close to the fiber end. In this case, end B can be tested further. If end B is wetted with water or saliva, there will be no significant change in the signature if there is a break in the cable between the OTDR and end B. If the cable is unbroken, the amplitude of the signature pulse will decrease substantially.

11. Compare the displayed value with the loss specification for the cable system under test.

6.3 TROUBLESHOOTING WITH THE OPTICAL TIME DOMAIN REFLECTOMETER (OTDR)

If a particular sequence of tasks is performed, an OTDR (Paragraph 4.2) can be used to locate breaks in short fiber optics cable assemblies, including breaks inside connectors. This ability greatly facilitates troubleshooting of suspect systems and makes practical isolation to the break site rather than to merely a cable segment.

Whenever an avionics system using fiber optics interconnect malfunctions, a number of methods are available to isolate the fault. If the fault cannot be immediately isolated to a WRA and both ends of the suspected interconnect are accessible, an OATS (Paragraph 4.1) is used to verify that there is indeed an open circuit in the interconnect. An OTDR can then be connected to an oscilloscope and to the faulty interconnect and the techniques set forth here are applied.

The method is illustrated first for a single fiber optics cable segment, and then for the more likely occurrence of multiple segments.

6.3.1 One-Segment Cables - The normal OTDR signature from a short one-segment fiber optics cable is shown in Figure L-5 and consists of two pulses, one from the launch end of the fiber (the launch pulse) labeled A, and one from the far end of the fiber (the signature pulse) labeled B. The length of the cable segment can be calculated given that 10 nanoseconds must elapse for each meter of cable length before the signature pulse can return. Thus, if the cable length is known, the location of all expected pulses can be easily calculated. Any pulses which are missing, or pulses which appear in unexpected locations, or even an apparently normal signature which does not pass the OATS test, may indicate a catastrophic fiber failure or other interconnect problem.

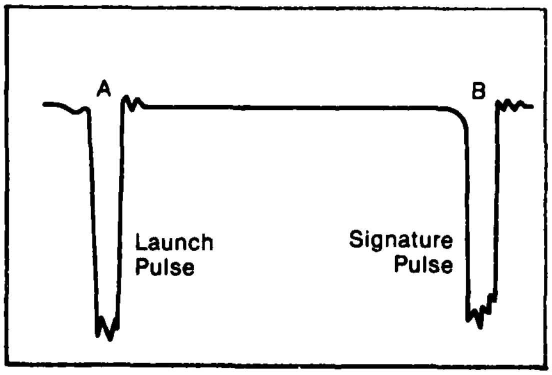

Figure L-5. Normal Signature

1. Dirt between the ends of the fibers in a connector. Since the fibers are so small, even a tiny speck of dust can block a relatively large amount of light passing through the fiber. Therefore, extreme care must be taken to ensure that no dirt is allowed to remain in the connectors when they are mated.

2. Damaged fiber ends. If the ends of the fiber are rough instead of being properly polished, the light will scatter instead of passing from one fiber to the other. The light that scatters does not continue to travel through the fibers and is lost.

3. Loose connection. If a connector is not properly mated, the fibers will not align properly and the ends of the fibers will not be close enough for all of the light to travel from one fiber to the other.

4. Broken fiber. If a fiber is broken, no light can travel past the break. This is analogous to a broken electrical wire.

6.2 OPERATION OF THE OPTICAL ATTENUATION TEST SET (OATS)

The OATS (Paragraph 4.1) can be used to measure the losses in a fiber optics cable. The cable to be measured may be only one segment, or several segments connected together, so long as there is only one input port and one output port in the system. In order to obtain accurate, repeatable measurements, the following steps must be followed.

1. Connect one jumper cable to the RECEIVE port of the OATS.

2. Connect another jumper cable to the TRANSMIT port of the OATS.

3. Connect the free ends of the two jumper cables together using a suitable adapter.

4. Enable the transmitter so that light will be transmitted through the jumper cables.

5. Adjust the ATTENUATION ADJUST control until the display reads 0.00. The test set is now zeroed and ready to perform the test measurement.

6. Disable the transmitter. Having the transmitter disabled when measurements are not being made will prolong the life of the optical source as well as the test set batteries (if applicable).

7. Disconnect the jumper cables from each other, but do not disconnect the cables from the OATS.

8. Connect the ends of the cable system under test to the free ends of the jumper cables. It does not matter which end of the cable under test is connected to which jumper cable.

9. Enable the transmitter.

10. Read the display. The number being displayed is the amount of loss (in dB) or the optical power transmitted (in dBm) in the cable system. These two units of measurement can be selected by a switch on the test set (if applicable).

1. A transmitter which converts electrical signals to light signals (See Figure L-3)

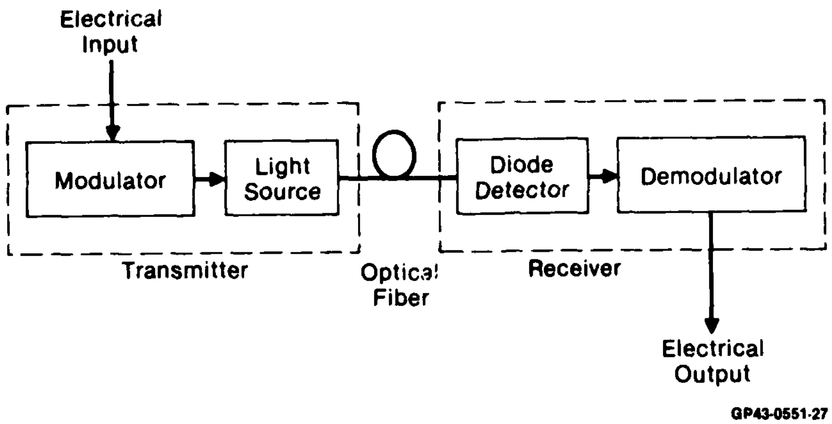

Figure L-3. Basic Fiber Optics Link

2. The fiber optics interconnect (cable-connector assembly) which carries the light signals from one point to another (See Figures L-3, L-4).

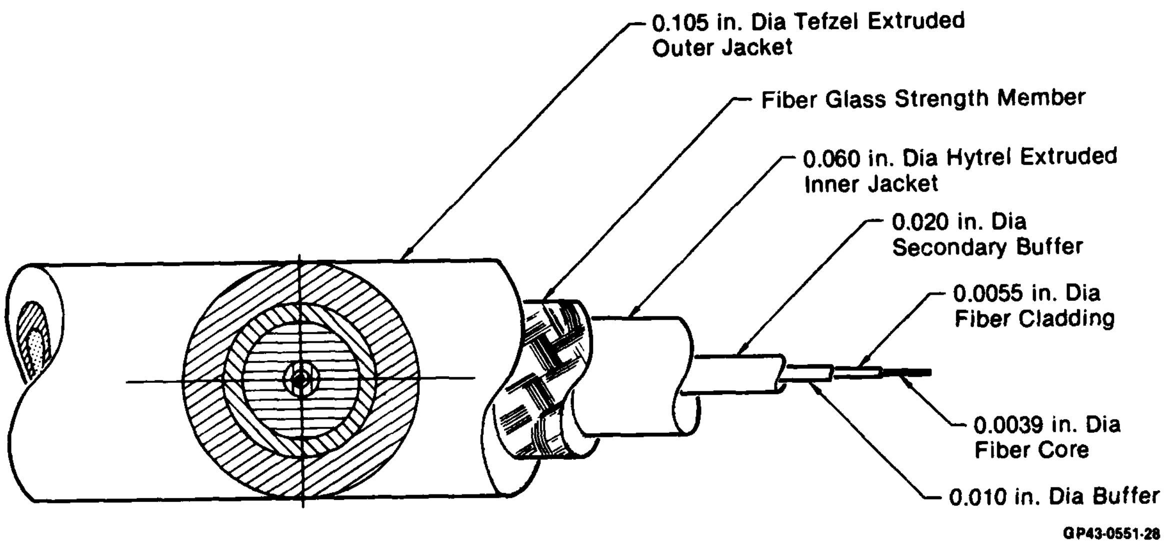

Figure L-4. Fiber Optics Cable

3. The receiver which converts the light signals back to electrical signals (See Figure L-3).

6.1.3 There are several conditions that can cause loss of light in a fiber optics interconnect system.

4.2 Optical Time Domain Reflectometer (OTDR). See Figure L-2.

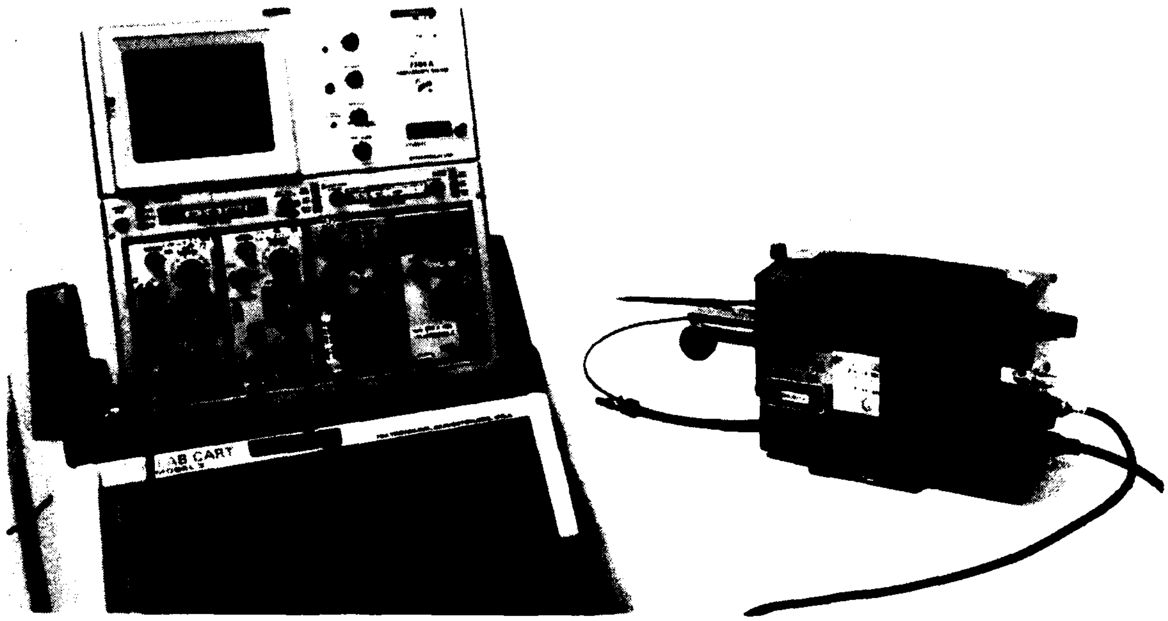

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Figure L-2. Optical Time Domain Reflectometer (OTDR)

4.3 Oscilloscope with time base to 10 nsec/div or faster. See Figure L-2.

5.0 REQUIREMENTS

5.1 Refer to 1760-TS1.

6.0 PROCEDURES

6.1 BASICS OF FIBER OPTICS

6.1.1 Fiber optics is a system for the transfer of data by transmitting light through a glass or plastic fiber which can be thinner than a human hair. The advantages of a fiber optics system over a coaxial or triaxial cable system are:

1) smaller size
2) lighter weight
3) lower cost
4) higher data rate capability
5) immunity to Electromagnetic Interference (EMI)
6) immunity to Electromagnetic Pulse (EMP)
7) immunity to lightning strikes.

6.1.2 A fiber optics data link consists of three major components:

FIBER OPTICS, AVIONIC, BASICS AND TROUBLESHOOTING OF

1.0 APPLICATION

1.1 This specification defines the procedures for troubleshooting fiber optics interconnects.

2.0 APPLICABLE DOCUMENTS

2.1 None.

3.0 MATERIALS

3.1 None.

4.0 EQUIPMENT

4.1 Optical Attenuation Test Set (OATS). See Figure L-1.

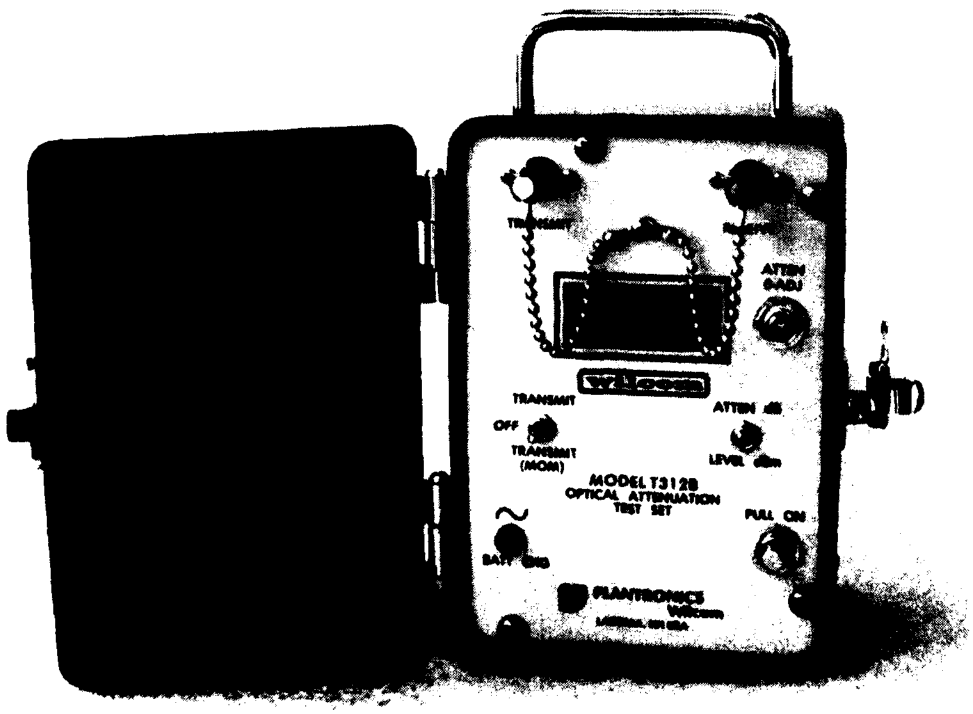

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Figure L-1. Optical Attenuation Test Set (OATS)

APPENDIX L

1760-PS4-TM - FIBER OPTICS, AVIONIC,
BASICS AND TROUBLESHOOTING OF

6.4.2.4 Adjust ATTEN-O-ADJ knob for 0.00 on display.

6.4.2.5 Insert the individual cable or cable system to be tested between the two cables.

6.4.2.6 Read the loss in dB in the display window.

6.5 CONNECTOR PROTECTION

6.5.1 When the connectors are unmated, cover the contacts with a plastic dust cap (Paragraph 3.5), a polyethylene bag (Paragraph 3.6) or other equivalent method to prevent damage or contamination.

7.0 QUALITY ASSURANCE PROVISIONS

7.1 Surveillance shall be maintained to ensure adherence to Section 5 requirements.

7.2 PROCESS CONTROL

7.2.1 Surveillance shall be maintained to ensure adherence to Section 6 procedures and restrictions.

7.3 ACCEPTANCE CONTROL

7.3.1 Verify that all connections are tight and that all cabling is installed in a neat, orderly manner.

7.3.2 Verify that all hardware (including unused) is tight and that proper hardware has been installed.

7.3.3 Measure the loss of each installed cable per Paragraph 6.4. Reject all cables which exceed the allowable losses listed in Table K-1. Use an OTDR (Paragraph 4.1.3) to locate faults in the cable. See Figure K-3.

8.0 SAFETY

8.1 GLASS FIBERS - Broken pieces of glass fiber shall not be permitted to remain loose in work area.

5.2.4.2 System Check - An end to end system check of the total cable losses per Paragraph 6.4.2 shall be made immediately after all cable segments are joined together. Refer to Table K-1 for acceptance criteria.

6.0 PROCEDURES

6.1 GENERAL

6.1.1 When installing harnesses in aircraft, conform to the standard procedure for installation of wire harnesses and the requirements of this specification.

6.2 CLEANING

6.2.1 Prior to mating, inspect the polished fiber ends for damage, contamination or debris. The socket contact especially should be inspected for debris. If debris is visible or if losses are excessive, use pressurized clean gas (Paragraph 3.1) to dislodge the debris. If pressurized clean gas is not available or is not successful, a metal probe may be used. Care must be taken not to damage contact parts or to scratch the polished fiber end. When the debris has been cleared, spray the tip of the fiber optics contacts with Freon TF (Paragraph 3.2), and wipe with optical wiping tissue (Paragraph 3.4) or Q-Tip. If Freon TF is not available, the fiber ends may be cleaned by dipping into or brushing with alcohol (Paragraph 3.3). Allow the contacts to dry for 30 seconds or longer.

6.3 COUPLING CONNECTORS

6.3.1 Position the plug of the connector so the keyway of the plug and receptacle align. Slide the coupling nut onto the receptable shell and turn the nut clockwise until the threads engage. Continue turning the coupling nut until fully engaged. When coupling MIL-C-38999 Series III connectors extra caution should be taken to insure that the contacts of the connector are engaged to a definite stop. When the receptacle is positioned so there is a clear view of the red line, tighten the coupling nut until the red line is no longer visible and the coupling nut will no longer turn. If the red line cannot be clearly viewed, tighten the coupling nut as far as possible by hand. Finish tightening the nut with an appropriate spanner wrench, or a leather or fabric strap wrench, until the connector bottoms out and the coupling nut will no longer turn.

6.4 TEST PROCEDURES

6.4.1 Continuity Check - Using a 2-cell "D" battery size flashlight (Paragraph 4.1.1) as a light source at either end of the test cable, visually check for light transmission between the cable ends.

6.4.2 Cable Loss Measurement - Measure cable loss using the OATS (Paragraph 4.1.2) test set as follows:

6.4.2.1 Connect the pigtail cable to the RECEIVE port of the OATS.

6.4.2.2 Connect other pigtail cable to the TRANSMIT port of the OATS.

6.4.2.3 Connect the two cables together.

COURSE, TRAINING, FIBER OPTICS, SPECIFICATION FOR

1.0 APPLICATION

1.1 This specification defines the assembly, installation, measurement techniques, and troubleshooting of fiber optics components in military aircraft.

1.2 This specification is applicable to the training of personnel to troubleshoot and repair fiber optics interconnect in military aircraft.

2.0 APPLICABLE DOCUMENTS

2.1 SPECIFICATIONS

MIL-W-5088 - Wiring, Aerospace Vehicle

1760-CS1 - Specification, Cable, Fiber Optics

1760-CS2 - Specification, Contact, Pin, Fiber Optics

1760-CS3 - Specification, Contact, Socket, Fiber Optics

1760-MS1 - Specification, Epoxy

1760-PS1-TM - Specification, Interconnect, Fiber Optics, Fabrication of (Training)

1760-PS2-TM - Specification, Interconnect, Fiber Optics, Installation, Aircraft (Training)

1760-PS3 - Specification, Interconnect, Fiber Optics, Maintenance/Repair Procedures, Aircraft

1760-PS4-TM - Fiber Optics, Avionic, Basics and Troubleshooting of

3.0 MATERIALS AND/OR SOLUTIONS

3.1 Refer to 1760-PS1.

4.0 EQUIPMENT AND FACILITIES

4.1 Refer to 1760-PS1.

4.2 Refer to 1760-PS2.

5.0 REQUIREMENTS

5.1 All personnel shall be required to complete this training course prior to performing any maintenance on fiber optics interconnect in military aircraft.

6.0 PROCEDURES

6.1 This training course shall consist of the following topics:

1) Basics of Fiber Optics
2) Fiber Optics Components
3) Assembly Procedures
4) Installation Procedures
5) Measurements
6) Troubleshooting.

6.2 BASICS OF FIBER OPTICS

6.2.1 Refer to 1760-PS4-TM.

6.3 FIBER OPTICS COMPONENTS

6.3.1 The components of a fiber optics interconnect with which maintenance personnel are concerned are cables and connectors.

6.3.2 Fiber optics cable

Refer to 1760-CS1.

6.3.3 Fiber optics pin contact

Refer to 1760-CS2.

6.3.4 Fiber optics socket contact

Refer to 1760-CS3.

6.4 ASSEMBLY PROCEDURES

6.4.1 Refer to 1760-PS1-TM.

6.5 INSTALLATION PROCEDURES

6.5.1 Refer to 1760-PS2-TM.

6.6 MEASUREMENTS AND TROUBLESHOOTING

6.6.1 Refer to 1760-PS4-TM

7.0 QUALITY ASSURANCE PROVISIONS

NOT APPLICABLE

8.0 SAFETY

8.1 Refer to 1760-PS1-TM.

8.2 Refer to 1760-PS2-TM.

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